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ENGINEERING ASSESSMENT

MHD RETROFIT STUDY

MILESTONE #5

REVISION OF DESIGN REQUIREMENTS

MOUNTAIN STATES ENERGY INCORPORATED
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BUTTE, MONTANA 59702

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ENGINEERING ASSESSMENT

MHD RETROFIT STUDY

MILESTONE #5

REVISION OF DESIGN REQUIREMENTS

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Mountain States Energy Inc.
POST OFFICE BOX 3662
BUTTE, MONTANA 59702

May 9, 1983 83MSE-058

Mr. Robert J. Robinson
Deputy Director
Department of Natural Resources and Conservation
32 South Ewing
Helena, Montana 59620

Subject: Engineering Assessment - MHD Retrofit Study

Reference: Agreement Between DNRC and MSE, November 1, 1982

Dear Mr. Robinson:

Submitted herewith are the results of Milestone #5, "Revision of Design Requirements", for the Engineering Assessment concerning an Advanced Test System, MHD retrofit to the J. E. Corette Plant in Billings, Montana.

Attachment #1 constitutes the Revised Design Requirements reflecting comments received from Project Reviewers of Milestone #4. Comments received thus far from Project Reviewers are given in Attachment #2 and specific comment responses are given in Attachment #3.

A visit was made to the Corette Plant on April 28, 1983 to confirm MHD system interface connections and plant layout arrangements, and to discuss MHD process considerations with plant personnel. A trip report for this visit is given in Attachment #4.

Attachment #5 consists of the invitation and mailing lists for a Project Review Meeting to be held in Butte on June 1, 1983. The invitations were sent to EEI MHD Task Force Members, Utility Representatives, and Project Consultants.

The effort to complete Milestone #5 is summarized in Attachment #6 which constitutes an invoice for activities through April 29, 1983.

If you have any questions, need additional information, or require any clarification, please let me know.

Sincerely,

JMSherick

J. M. Sherick
President

EWA/JMS/lc

Attachments:
1) Revision of Design Requirements
2) Project Review Comments
3) Comment Responses
4) Corette Plant Trip Report
5) Project Review Meeting Invitation
6) Invoice, Milestone #5
7) Estimate, Milestone #6
8) Milestone Schedule and Status Report

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ATTACHMENT #1

Revision of Design Requirements

RETROFIT DESIGN REQUIREMENTS OF AN MHD ADVANCED TEST SYSTEM

SUBMITTED BY

MOUNTAIN STATES ENERGY, INC.
P.O. BOX 3662
BUTTE, MONTANA 59702

SUBMITTED TO

MONTANA DEPARTMENT OF NATURAL
RESOURCES ANDCONSERVATION
32 SOUTH EWING
HELENA, MONTANA 59620

MAY 1983

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RETROFIT DESIGN REQUIREMENTS OF AN MHD ADVANCED TEST SYSTEM

INTRODUCTION AND SUMMARY

1.1 Summary

The design requirements for the engineering, environmental, and socioeconomic aspects of retrofitting an existing steam plant with a magnetohydrodynamics (MHD) Advanced Test System (ATS) are presented herein. Within the engineering discussion, the requirements are organized as follows: 1) the primary MHD components; 2) the necessary support systems; 3) the resulting interface with existing plant systems; 4) site requirements; and 5) the modifications necessary to complete the retrofit. The environmental and socioeconomic sections include requirements specific to Montana and the selected plant are discussed. In addition, identifiable national environmental and socioeconomic requirements are presented to assist in planning a retrofit at a plant outside of Montana.

The primary MHD components have conservative design requirements, as might be expected with a primary objective of operational consistency. The most significant aspects of the power train are a 250 MW_t coal-fired combustor, a supersonic channel, and a 4.5 Tesla superconducting magnet.

The MHD support systems, (e.g., coal preparation, oxidizer, substation) are typical of those systems required to support the power train system. Specific aspects of interest are the oxidant and effluent handling systems.

The oxidant system will supply 70 mole % oxygen through an optimized process cycle employing electrically driven compressors. The effluent handling system minimizes water consumption and discharge by treating and recycling water.

Interfaces with the utility were selectively chosen to lessen operational interferences while utilizing available systems. As this retrofit concept is presently defined, the primary interfaces will be in the feedwater, superheat, and reheat steam lines. These lines will be monitored and controlled to provide adequate distribution to both the existing and retrofit plants. Consequently, both plants will provide superheated steam to the turbine-generator. Control will be accomplished by a supervisory computer which is compatible to both plants and operated by the utility personnel.

Other existing plant systems that provide services to the ATS are various water, fuel, and electrical systems. Existing water intake and discharge structures will be used, as will the city water service lines. Coal handling will be integrated to the extent possible. A more detailed design will be necessary to define the most desirable location. Natural gas is already available on site; thus, the gas system will be extended to encompass the Heat Recovery Seed Recovery - HRSR (MHD boiler) where it will be used for start-up and other transient modes. Electrical power will be obtained from the present main switchyard and the MHD generated power will be sent through the same point, a 100 KV ring bus. Both incoming and outgoing power will go through a new substation in the proximity of the ATS. Some building and road dislocation will be necessary but should be minor. The old construction building and some outside materials storage will have to be moved. The only other existing building to be affected will be that containing the present

control room. The ATS control room will be located adjacent to that building. Other siting requirements can be satisfied by use of existing open spaces; the possible exception is waste disposal. Solid waste from the ATS will be temporarily stored on-site, then transported off-site for disposal or reprocessing for seed. All other site requirements are what would be expected of any plant and can be satisfied without any apparent difficulty during the preliminary design phase.

Modifications to the existing plant follow the interface points, with the primary changes to be made in the feedwater, reheat and superheat steam lines, and the plant control system. Although any disruption or changes to existing plant systems must be considered carefully before implementing those modifications, it does not appear from this limited review that the modifications should be considered risky or excessively time consuming.

From an operational point of view the single most important point is that control of both plants will be through the utility plant operator. All changes, planned or unplanned, will be the responsibility of the utility to respond to, or to implement.

Environmental requirements center around applicable laws and regulations. However, at this time it appears that the bottom line is this: air emissions from the retrofit plant should be less than that produced by the present Corette plant; but existing local air quality will necessitate analysis and testing to verify lesser impacts. Liquid waste should meet the existing water discharge permit requirements, particularily in regard to heat discharge. Solid waste discharge is non-hazardous and will be addressed during plant permitting for disposal by conventional methods. High potassium

fly ash will be stored off-site for future processing to recover potassium. This plant will have its own site specific concerns. Industrial safety concerns will be fairly standard, except for the high magentic field surrounding the superconducting magnet.

Socioeconomic requirements will be minimal and normal for the construction and operation of a small coal-fired power plant; foreseeable effects tend to be positive.

1.2 Objectives

The primary objective of this portion of the project study is to develop design requirements for the retrofit of an existing coal-fired power plant with a MHD Advanced Test System. The conventional power plant selected for the study is the Corette Power Plant, a Montana Power Company (MPC) facility located in Billings, Montana.

Throughout the following discussion of retrofit requirements particular design emphasis has been given to providing the most favorable conditions for demonstrating consistent, on-line MHD operation in a utility setting. Development of these design requirements were based on the several guidelines that determined the extent and depth of the study, as detailed below:

- Follow the general requirements developed in Phase I by MPC and the Edison Electric Institute MHD Task Force.

- Develop and describe the engineering, environmental, and socioeconomic requirements in sufficient detail to enable the practicality of retrofitting the Corette and similar plants. Purpose of the requirements is to provide a foundation for the next project phase; i.e., a Preliminary Design.

- Minimize impacts on the existing plant while also minimizing cost of the retrofit. This was to be accomplished by careful selection of the interfaces between the two plants, while incorporating the MHD power train components defined in the previous performance analysis.

- Identification of secondary objectives:
  - Evaluate the practicability of retrofitting a plant that will use steam from two boilers to power a single turbine-generator.
  - Provide the capability of fully using the existing turbine-generator capacity; a potential increase of 19 MW_e (about 12%).

- Structural study objective:

  - Utilize and elaborate upon previous retrofit studies. Those that were particularly helpful are listed in the reference section of this document.

1.3 Assumptions

Implicit in any discussion of a large MHD system is the assumption that the larger power train components will be available when required. Recommendations for specific development goals to support the ATS will be made later in the study.

Assumptions of a more specific nature that assist in defining the ATS requirements and integration into the existing plant are these:

- Heat reclaimed from the cooling of the CFC, channel and diffuser can be effectively and efficiently used to preheat the feedwater before it enters the MHD boiler (Heat Recovery Seed Recovery - HRSR)

- HRSR bottom ash and fly ash (all containing potassium compounds) will be recovered in the HRSR and the particulate control device. This assumes that insignificant amounts of seed will be deposited with the CFC slag. Therefore, the slag may be handled and deposited with no concern for potassium, while the recovered bottom ash and some or all of the fly ash will contain high concentrations of potassium.

- Bottom ash or fly ash will not be processed to recycle the potassium into the CFC. The recovered material from the flow train will be stored off-site and processed later at a separate facility.

- Firing of the HRSR with natural gas warm up guns is desirable during ATS startup or off-load transients.

- Feed water and reheat steam can be valved and controlled in an acceptable operational manner. Sufficient flow of feedwater will be available to the ATS during reductions in Corette operations.

- Heat from the thyristors in the inverter cannot be recovered and will be dissipated to the atmosphere.

- Compressors will be electrically driven instead of stream driven to simplify the initial system and to lessen impacts on the existing turbine condensing and feedwater system.

- Control of the entire plant will be through the utility plant operator.

- All systems will be required to support various test objectives, particularily the instrumentation and data acquisition systems.

1.4 Special Code Requirements

The facility design and equipment supplied shall comply with applicable federal and industry regulations, codes, and standards. All codes and standards used shall be the latest edition, including revisions or supplements in effect at the time of design and construction.

The ATS plant design, design and fabrication of the equipment, installation, materials, and workmanship shall comply with the following codes and standards as applicable.

- Air Conditioning & Refrigeration Institute Standard (ARI)
- Air Moving & Conditioning Association (AMCA)
- The Anti-Friction Bearing Manufacturer's Association (AFBMA)
- The American Gear Manufacturer's Association (AGMA)
- The American Institute of Steel Construction (AISC)
- The American National Standards Institute (ANSI)
- American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE)
- American Society of Mechanical Engineers Boiler and Pressure Vessel Codes (ASME)
- The American Society for Testing and Materials (ASTM)
- The American Welding Society (AWS)
- Crane Manufacturer's Association of American, Inc. (CMAA)
- Factory Mutual (FM)
- Federal Aviation Administration (FAA)
- Hoist Manufacturers Institute (HMI)
- Illuminating Engineers Society (IES)
- Institute of Electrical and Electronic Engineers (IEEE)
- Instrument Society of America (ISA)
- Insulated Power Cable Engineers Association (IPCEA)
- National Bureau of Standards (NBS)
- The National Electrical Code (NEC)
- The National Electrical Manufacturer's Association (NEMA)
- National Electrical Safety Code (NESC)

- National Fire Code of the National Fire Protection Association (NFPA)
- National Plumbing Code (NPC)
- The Mechanical Power Transmission Association (MPTA)
- The Occupational Safety and Health Administration (OSHA)
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
- The Steel Structures Painting Council (SSPC) "Steel Structures Painting Manual"
- Underwriters Laboratories (UL) (All equipment shall be U.L. listed)
- Uniform Building Code (UBC)

2.0 ENGINEERING REQUIREMENTS

2.1 MHD System

2.1.1 Coal-Fired Combustor and Nozzle

The coal-fired combustor should be designed to burn Montana Rosebud coal dried to 5% moisture content, at a flow rate of 79480 lbm/hr (10.0 kg/sec), and a combustion pressure of 5.83 atm, with an oxidizer flow rate of 366030 lbm/hr (46.16 kg/sec). The combustor should accept a seed flow rate of 7870 lbm/hr (0.992 kg/sec) of dry potassium carbonate and should reject at least 85% of the slag. Since the combustor will be at a 21 KV electric potential during MHD power generation, some form of electrical isolation must be provided to isolate the support structure and the various supply systems from this high electrical voltage. The combustor should be designed to operate at a stoichiometric equivalence ratio of 0.95, and should deliver a reasonably uniform flow at the nozzle entrance. The second-stage combustor and MHD channel walls should be constructed of non-ferromagnetic materials and should be water-cooled, using demineralized water to provide the required electrical isolation.

The function of the nozzle is to accelerate the gas flow to a Mach number of 1.2 at the nozzle exit. The nozzle walls should also be water-cooled and should be constructed of non-ferromagnetic material.

2.1.2 MHD Generator

The MHD generator should be of the supersonic, diagonal conducting wall type, 10 meters in length, with the approximate internal dimensions as shown in the Configuration Analysis (as presented in a previous report of this study). The exact internal and external dimensions will be determined in part by constraints on the magnet geometry, as explained below. The generator will be of the linear type, with segmented electrodes on opposite walls. The electrode spacing and pitch should be such as to ensure that the insulating regions do not break down due to Hall field effects or excessive arcing. It is suggested that the Hall field and transverse current density should be limited to the values $(E_x)_{crit}$ = 2500 volt/meter and Jy-crit = 1 Amp/cm^2, to ensure that this condition is met. The generator should be constructed of non-ferromagnetic materials and should have water-cooled walls, and should operate with an enthalpy extraction at its design point of at least 10.0%.

2.1.3 Diffuser

The function of the diffuser is to decelerate the high-velocity flow out of the generator and to recover as much of the stagnation pressure as possible. The diffuser will consist of two sections: A uniform supersonic recovery section and a diverging subsonic recovery section. The diffuser will be designed to give an exit static pressure of 1.0 atmosphere (absolute) also to minimize stagnation pressure losses due to shock waves and viscous wall effects. The diffuser should be constructed of non-ferromagnetic materials and should have water-cooled walls.

2.1.4 Superconducting Magnet System

This description applies to the conceptual design of a magnet system to provide the magnetic field required for a supersonic MHD channel intended to produce approximately 29 MWe.

The magnet should have a rectangular bore, a 10 meter active length, and a warm bore liner consisting of a water jacket through which cooling water is pumped. It should be designed to give a field of 4.5 Tesla along the active length. Significant performance benefits can be realized by carefully tailoring the magnet bore size, bore aspect ratio, bore divergence, and taking into account the generator geometry. Therefore the design efforts for the magnet and the MHD channel should proceed in tandem, with close interaction between the two efforts.

The system consists of the magnet and accessory equipment, with subsystems as listed below:

- Magnet assembly, including warm bore liner
- Cryogenic support equipment
- Power supply and magnet discharge equipment
- Vacuum pumping equipment
- Protection/control equipment and instrumentation
- Cryogenic system

2.1.4.1 Magnet Assembly

The magnet assembly consists of liquid helium cooled superconducting coils in a cryogenically-insulated enclosure (vacuum vessel) with a cavity (warm bore) extending through the center horizontally, open at both ends. A water-cooled warm bore liner is provided inside the cavity. The outline dimensions of the magnet assembly and the dimensions of the cavity (inside liner), which diverges from plasma upstream (inlet) to plasma downstream (exit) end, are shown on Figure 2.1. The cavity is designed to house the MHD channel, which is inserted and withdrawn from the large exit end opening. The magnetic field in the cavity is oriented in a primarily horizontal direction perpendicular to the long axis of the cavity. The magnet does not incorporate a ferromagnetic flux-return-path or other means to reduce fringe magnetic fields. The magnet is designed to be stationary, permanently mounted on a foundation provided as a part of the power plant facility. Design characteristics are summarized in Table 2.1. The windings are designed to produce the on-axis profile shown on Figure 2.2.

2.1.4.2 Cryogenic Support Equipment

The cryogenic support equipment consists of a helium refrigerator/liquefier, a helium compressor package, storage tanks, heat exchangers, transfer lines and controls as required for cooling down the superconducting magnet windings, maintaining them continuously at liquid helium temperature during facility operating and standby periods, and warming up the windings when an extended dead plant condition is anticipated.

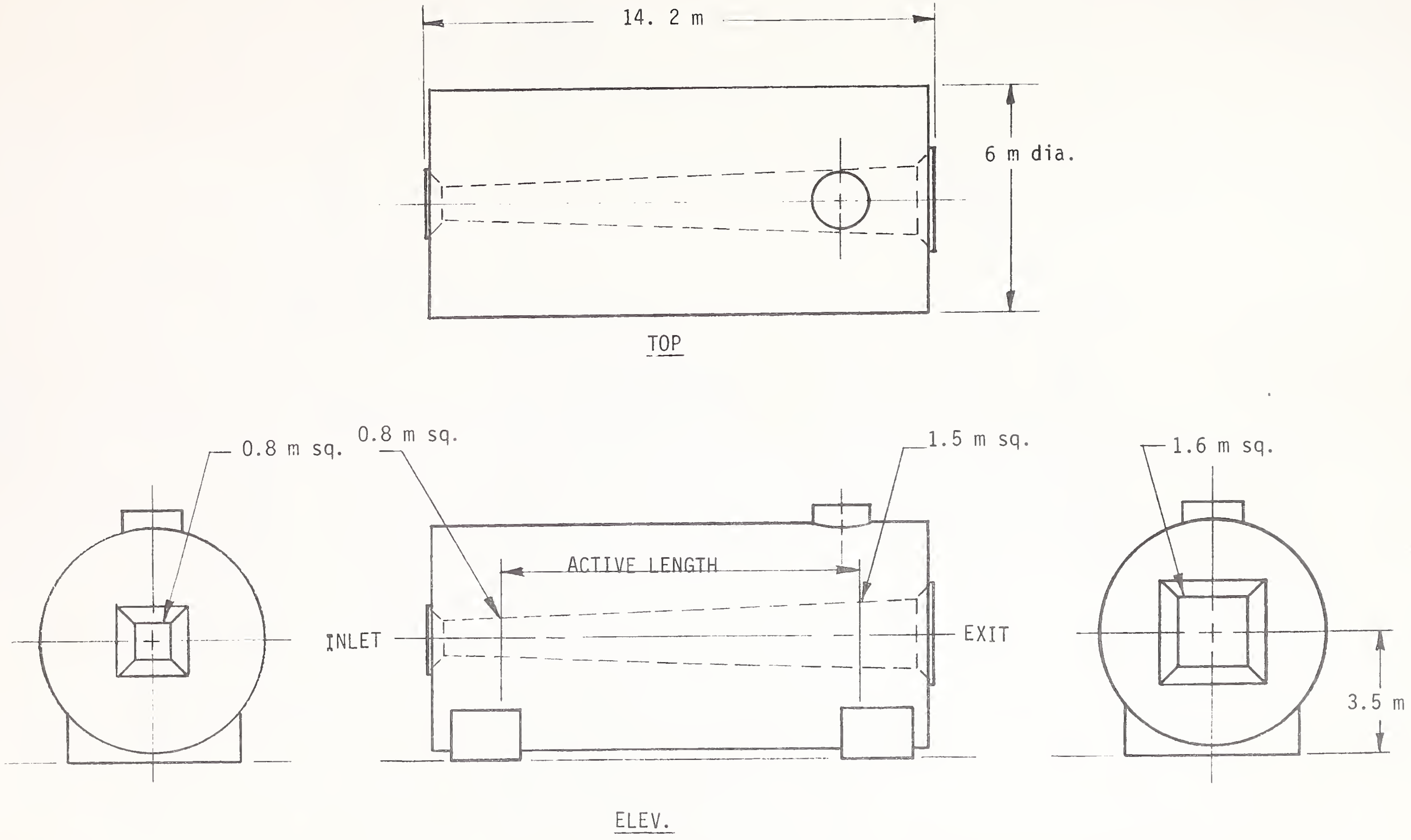


Figure 2-1 -- Superconducting Magnet Dimensional Schematic

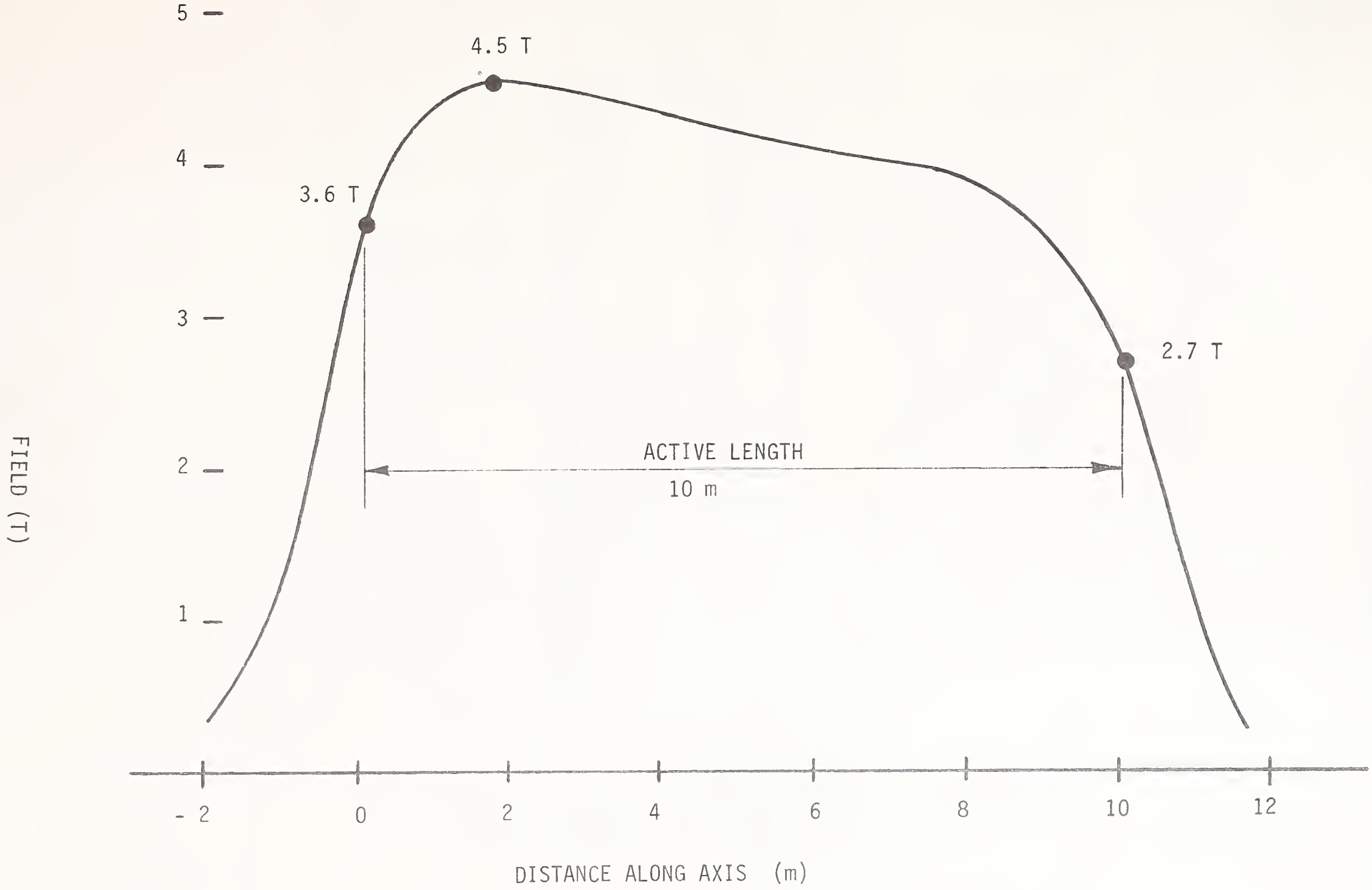


Figure 2-2 -- Curve of On-Axis Field Vs. Distance Along Axis

TABLE 2-1
MAGNET DESIGN CHARACTERISTICS

Magnetic Field:	
Peak on-axis field	4.5T
Active field length	10 m
Field at start of active length	3.6T
Field at end of active length	2.7T
Dimensions:	
Aperture, warm bore inlet*	0.8 m x 0.8 m
Aperture, start of active length*	0.8 m x 0.8 m
Aperture, end of active length*	1.5 m x 1.5 m
Aperture, warm bore exit*	1.6 m x 1.6 m
Vacuum vessel overall length, including water-cooled warm bore liner	14.2 m
Vacuum vessel outside diameter	6 m
Winding Characteristics:	
Design current	20,000 A
Winding current density (J)	1.4×10^7 A/m^2
Ampere turns	15.2×10^6
Inductance	3.5 henries
Stored energy	700 MJ
Weights:	Tons
Conductor	75
Substructure	60
Superstructure and coil containment vessels	125
Thermal radiation shield, cold mass supports, etc.	20
Vacuum vessel	80
Miscellaneous	10
Total Magnet Weight	370

*Inside water-cooled warm bore liner

2.1.4.3 Power Supply and Utility Requirements

The power supply and discharge equipment consists of a rectifier-type DC power supply, discharge resistors, circuit-breakers and controls as required for charging the magnet, maintaining it at the desired field strength during MHD generator operation and discharging it under both normal and emergency (fast) shut-down conditions. Utility requirements describing electric power, cooling water and liquid nitrogen are summarized in Table 2-2.

TABLE 2-2

MAGNET SYSTEM UTILITY REQUIREMENTS

Electric Power (60 Hz)

	Voltage	Power Requirements	Phase
Power supply - Maximum charging & starting	4160 V	750 KW	3
- Steady state of operation	4160 V	250 KW	3
Refrigerator/liquefier	220 V	8 KW	3
Refrigerator compressors	440 V	350 KW	3
Utility vacuum pump	220 V	15 KW	3
Diffusion pumps, main vacuum (2)	440 V	24 KW	3
Fore pumps, main vacuum (2)	440 V	20 KW	3

TABLE 2-2

MAGNET SYSTEM UTILITY REQUIREMENTS

(Cont'd)

Cooling Water (80°F max., 50 psig except 100 psig for warm bore liner)

		Flow Rate
Power supply (rectifiers; diodes)		25 GPM
Discharge resistors		30 GPM
Refrigerator compressors		110 GPM
Refrigerator/liquefier		3 GPM
Diffusion pumps, main vacuum (2)		5 GPM
Four pumps, main vacuum (2)		5 GPM
Warm bore liner	Steady-state	30 GPM
	Emergency	150 GPM
Water-cooled power bus		25 GPM

Liquid Nitrogen (30 psig)

	Liter/Hr
Refrigerator pre-cooling (steady-state)	110
Magnet radiation shield, transfer lines, etc. (steady-state)	40

2.1.4.4 Vacuum Pumping Equipment

Vacuum pumping equipment consists of diffusion pumps and mechanical pumps for evacuating the magnet vacuum vessel prior to and during initial magnet cooldown and for removing from the vacuum vessel any helium leakage that may occur from the coil container during magnet operation. A utility vacuum pumping system for servicing the cryogenic support equipment is also provided.

2.1.4.5 Protection/Control Equipment

Protection and control equipment consists of instrumentation to detect abnormal conditions in the magnet system and controls to automatically activate protective measures. Low (breathing) oxygen detectors will be strategically located in the area to satisfy safety considerations.

Also included are instruments and controls to permit remote monitoring and manual control of major functions of the magnet and associated equipment at the power plant control room.

The magnet system includes, in addition to the above subsystems, piping and wiring necessary to interconnect subsystem equipment items and to connect these items to local utility outlets provided as part of the facility.

2.1.4.6 Cryogenic System

The magnet is contained in a cryostat, a superinsulated container which is also filled with liquid helium to maintain a superconducting temperature of 4.5°K in the magnet coils.

The helium refrigeration system provides for the initial cooldown of the superconducting magnet and subsequent maintenance of the magnet operating temperature.

- Cooldown of the Magnet

  The initial cooldown of the magnet is accomplished by reducing the temperature slowly to minimize stress. Gaseous helium cooled by liquid nitrogen exchange is recirculated to the magnet cryostat until a temperature of about 80°K is achieved.

  The second stage cooling from 80°K to the operating temperature of 4.5°K or less is accomplished by liquid helium from the storage dewar. The rate of cooling is controlled by the Liquid Helium Feed. Cooldown requires about 20 days to minimize thermal stress on the magnet. When the cooldown is complete, liquid helium accumulates in the magnet cryostat. When the operating level is achieved, the system is ready for startup.

o Normal Operation

The reliquefied helium begins during the cooldown. The liquid helium flows to the storage dewar which is maintained at atmospheric pressure.

Liquid helium is either continuously or intermittently fed into the magnet cryostat to maintain the operating liquid level.

Boil-off is returned to the liquefier. When the reliquefier is dynamically balanced with vaporization rate, the compressor capacity is adjusted to maintain the vaporization pressure, i.e., at 4.5°K the vaporization gas must be maintained at atmospheric pressure. Any change in heat load will result in a change in gas flow which is automatically compensated by compressor output. The compressor is the basic inventory control.

Figure 2-3 is a basic flow diagram for a helium refrigerator-liquefier system.

Helium inventory is contained in five places: (1) Liquid in SCM Cryostat; (2) Liquid & Cold Gas in Storage Dewar (3) Gas in L.P. Surge Gas Container; (4) Inventory in Liquefier; and (5) H.P. Cylinder Bank.

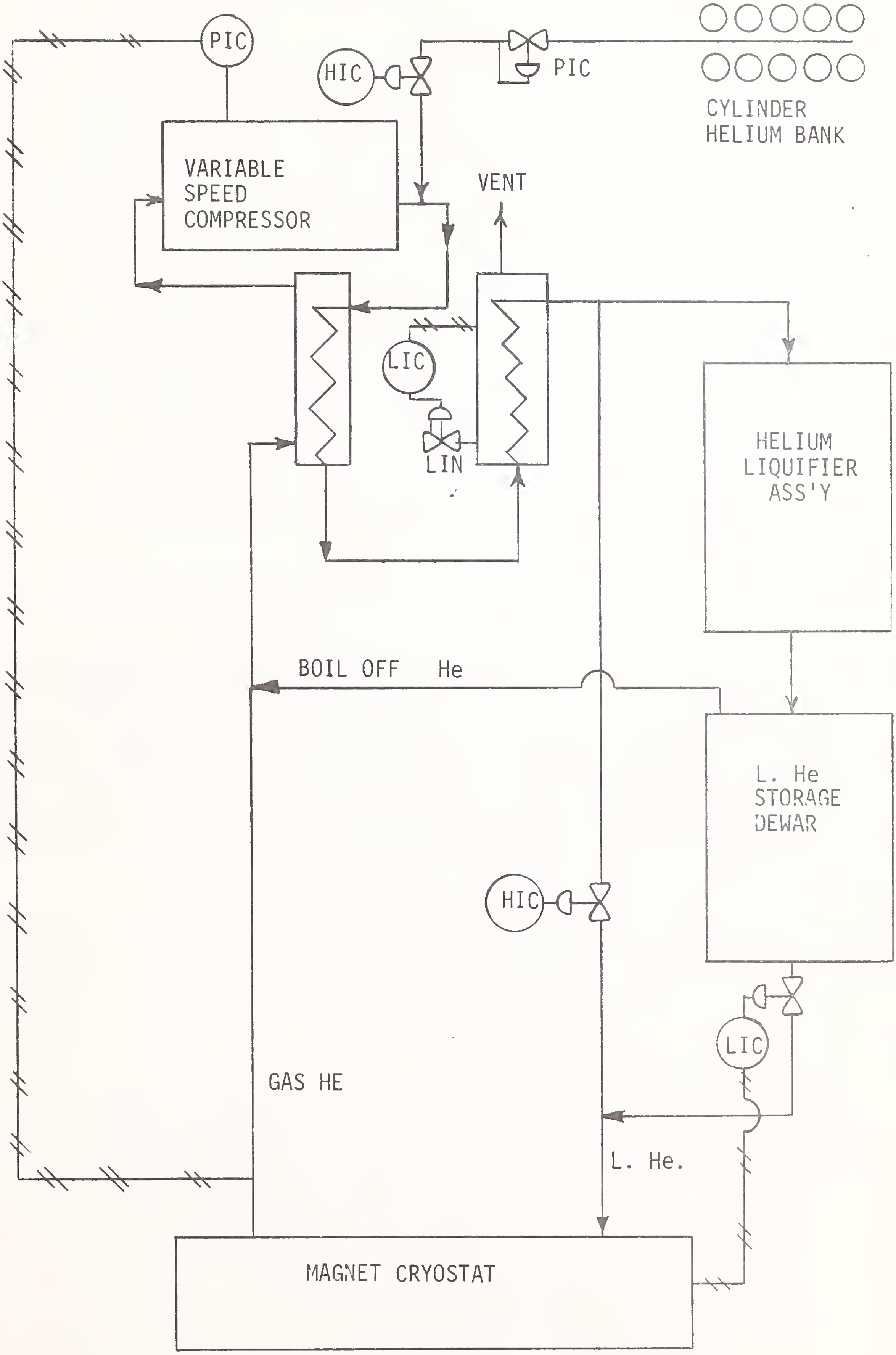


Figure 2-3 -- Helium Refrigeration System

- Compressor Design Considerations

  Special consideration should be given to the compressor beyond its duty as liquefier, as it is the primary control device for a wide range of gaseous nitrogen flows from the SCM cryostat. A variable speed drive compressor or other means of wide range control, such as valve unloaders, should be used. Temperature control of the magnet cryostat is dependent upon vaporizing pressure. The compressor must be capable of maintaining at or near atmospheric pressure over the vaporizing helium liquid and replace the liquid in the storage dewar at the rate of withdrawal.

- Storage Vessel (Dewar)

  The storage vessel should be large enough to provide for major liquid replacement but minimum size for minimum heat. The larger the vessel, the lower the heat leak as a percentage of the total volume, but the larger the vessel the greater the heat leak and reliquefied power required. The vessel will be minimum size, superinsulated, and liquid nitrogen shielded to satisfy the requirement for minimum heat leakage.

  The storage vessel should be located as close to the magnet dewar inlet as possible for minimum heat leak. A second floor location of the dewar and helium liquefier has been selected to achieve minimum distance location. Of equal importance, gravity-head permits the dewar to be maintained at atmospheric pressure for minimum boil-off in the cryostat during liquid transfer.

- Transfer Lines

Superinsulation and liquid nitrogen tracing is recommended on the transfer lines. Lines should be designed for low pressure drop on liquid and cold gas return to liquefier.

Bellows should probably be used except on very short sections. The thermal shrinkage of the inner pipe as the outer jacket is substantial. Utilization of elbow movement for shrinkage is generally unsatisfactory and produces excessive heat leaks that are unacceptable operationally and in power costs.

Consideration should be given to requiring liquid helium heat leak and integrity testing of installed pipelines by the fabricator. While this is expensive, a bad line will quickly cost more in heat losses or by requiring replacement.

Workmanship is equally important to design. The fabricator and all key equipment should be thoroughly checked-out before selection. Continuing inspection during fabrication is recommended.

- Air Leakage into Helium

Air leaks into the system are frozen into air-ice which can produce pluggage thereby shutting down the system. Careful design and fabrication, preliminary purging by repetitive evacuation and

filling with gaseous helium to ensure system integrity are more than repaid economically.

- Magnet Power Leads

The 11,000 amp feeders are a major source of heat leak at the juncture into the cryostat. It is suggested that these leads be liquid nitrogen cooled. A dual benefit can be achieved, that is reduced conductor resistance and reduction of heat transmission into cryostat.

- Portable Insulating Vacuum Pumping System

It is essential that a vacuum pumping equipment assembly be available to restore insulation vacuum on transfer lines, dewars, and cryostats.

The equipment should be mounted on a wheeled cart for maximum portability. The pumping equipment must be moved as close as possible to the equipment being evacuated for rapidity thereby achieving the best vacuum. Vacuum systems piped to a central station are notoriously unsuccessful.

- Cylinder Storage System for Helium

A reserve storage of helium gas for loss makeup is recommended. At least 25 cylinders should be manifolded together for emergency makeup with 25 additional cylinders in reserve in anticipation of reasonable loss requirements. Any larger amount of storage is not recommended due to the air and water contamination experienced in low-pressure storage. Initial filling of the system would be accomplished by tank truck. Since these cylinders are reserve, they will not be refilled frequently and purchase rather than paying demurrage would be less costly.

2.1.5 Heat Recovery, Seed Recovery System

The functions of the Heat Recovery System are to generate steam from the exit combustion gases of the MHD power train and also to supply approximately 30 MW_t of oxidizer preheat. An additional requirement is that the bottom ash and fly ash (containing seed mixtures) must be removed and collected at several points through the system.

As shown on the ATS schematic, the MHD power train and heat recovery system will supply 33% of the total steam requirement for the turbine generator. Steam generation will be accomplished through the use of water walls in the radiative section of the HRSR. Superheating for both primary and reheat steam will be accomplished by pendant type superheaters located in the convective region of the HRSR. The convective section is split into two separate legs in order to provide a means of controlling the relative balance

between oxidizer heating and superheating. The two gas stream flow rates will be controlled by dampers installed near the bottom of each leg. Special design considerations will be made to alleviate the cold end corrosion and contamination problems associated with dampers located in these areas.

A major consideration during the actual design of the HRSR is going to be the allowances for expansion and contraction of the unit during operation. The support elevation of the HRSR should be at the elevation of the centerline of the MHD power train. That centerline and diffuser connection will be at a fixed point and be unable to adjust to HRSR movement so care is required in the design connections.

The superheat and reheat steam that is supplied by the HRSR system must be closely matched in pressure and temperature to the respective steam flows that are supplied by the Corette boiler. The required exit steam conditions at design point operation are shown in Table 2-3.

Table 2-3

BOILER STOP VALVE STEAM CONDITIONS FOR CORETTE BOILER AND HRSR

	Corette			HRSR		
Superheat Steam	7.462×10^5W	1481H	1905P	3.675×10^5W	1481H	1905P
Inlet Reheat	6.363×10^5W	1345H	494P	3.134×10^5W	1345H	491P
Exit Reheat	6.363×10^5W	1524H	481P	3.134×10^5W	1524H	481P
Feedwater	7.500×10^5W	445H	463F	3.692×10^5W	445H	463F

NOTE: In the above table the letters W, P, and H have the following interpretation:

W lbm/hr
P lb/in^2 (abs)
H BTU/lbm

The radiant section of the heat recovery system will be designed to allow a 2 second gas residence time for equilibration of NO_x.

A large amount of flue gas recirculation will be required to regulate the temperature in the transition region at the end of the radiant furnace section. The recirculated flue gas will be injected along with the secondary air through a series of slots in the roof of the radiant furnace. Slag collection will be accomplished by employing a wet bottom ash type of collection system.

Since both the existing Corette boiler and the HRSR system will be generating steam during combined cycle operation, a means of merging the two flows must be provided. This control will be accomplished by controlling the amount of feedwater flow into each system, and in addition controlling the reheat balance by the use of steam valves in each of the two cold reheat legs.

2.1.6 Inverter

The configuration analysis previously done in this study predicts a DC output from the channel of 20.5KV and a power output of 28.7MW-DC. The purpose of the inverter is to convert the DC output to AC and to refine it to a quality that will be compatible with commercially produced power. The design of the inverter will accommodate 30MW of DC power at the input and through the use of taps in the transformers the AC inverter output voltage will be compatible. (See Figure 2-4).

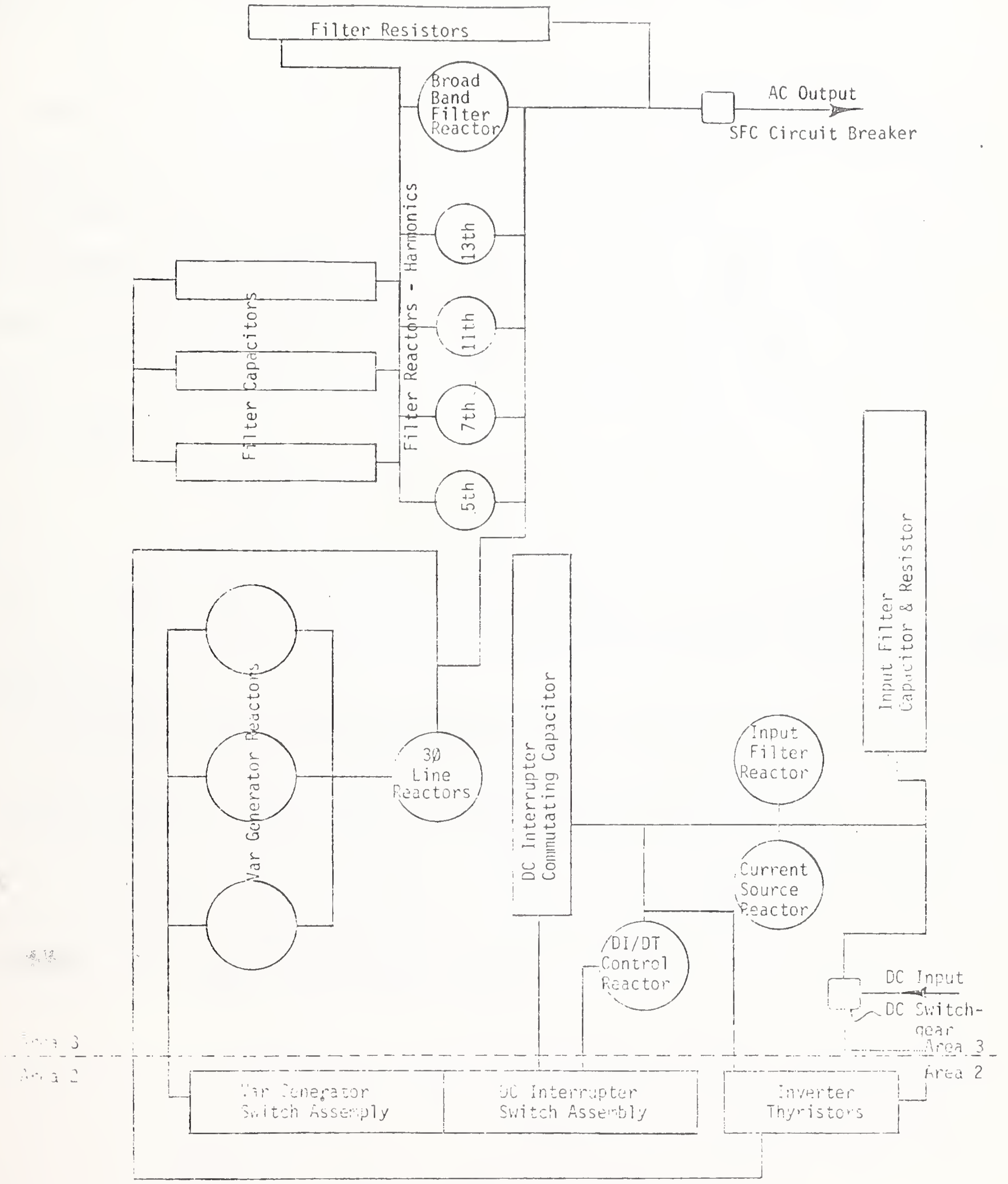


Figure 2-4 -- Corette ATS Inverter Schematic One-Line Diagram

The inverter for the Corette retrofit will be quite similar to the one at the Component Development and Integration Facility (CDIF) in States Energy in Butte, Montana, except for some refinements and improvements noted in this text.

It is generally agreed that except for switchgear, the CDIF inverter is capable of 8 MW to 10 MW of through-put. The CDIF installation is receiving approximately 10,000 volts DC from the channel and experiences a voltage rise to 11.6 KV at the AC output of the inverter. If this ratio holds true in the planned installation an input of 20.5 KV to the inverter will provide an AC output of 23.8 KV and standard equipment can be used by using a 5% tap in the transformers.

The output from the channel will be put on two standard isolated phase copper buses rated at 25 KV and 2000 amperes. This bus will be fully protected from any contact with external objects and there will be no possibility of a fault occurring on it.

A suggestion made by the Electric Power Research Institute (EPRI) is to use two 6 pole rectifiers to provide a 12 pulse unit. This could cause one half of the equipment in the harmonic and power factor correction section (area 3 at CDIF) to disappear and not be required.

Considering all of the other valuable suggestions and input that have been made (Westinghouse and Stanford Research Institute) regarding the inverter there is now a basis for planning and building the inverter.

Similar to the CDIF installation, the inverter system will be divided into three areas. Area 1 is the control section, Area 2 the converter switching assemblies and VAR generator section, and Area 3 the harmonic and power factor correction section.

It is generally agreed that Area 1 and 2 of the proposed facility should be double the size of that at CDIF and that Area 3 should be about 1.5 times as large as that at CDIF.

Experience with Area 2 at CDIF indicates a need to install this equipment in a long continuous line. This section of the present CDIF building is 35 ft wide, therefore, the ATS building will be 70 ft in width. It appears that a building 70 ft by 125 ft with an eave height of 24 ft will be adequate. The inverter building will be located adjacent to the building that houses the channel in order to keep to a minimum the length of bus from the channel to the inverter.

2.1.7 Instrumentation and Control

Some of the general considerations that arise in designing a control system include:

- o Who will exercise control?
- o What modes of control are needed? and,
- o How should the control system be organized?

Since it is planned to integrate the MHD system with an existing utility power plant, the ultimate control will need to reside in the hands of the utility plant management. In the case of an MHD plant combined with a conventional steam plant of similar size, one suitable control scheme would be to implement a supervisory control layer with ultimate control over both plants. The supervisory layer would be operated by the utility plant operator. MHD testing would be carried out with the consent of the utility superintendent.

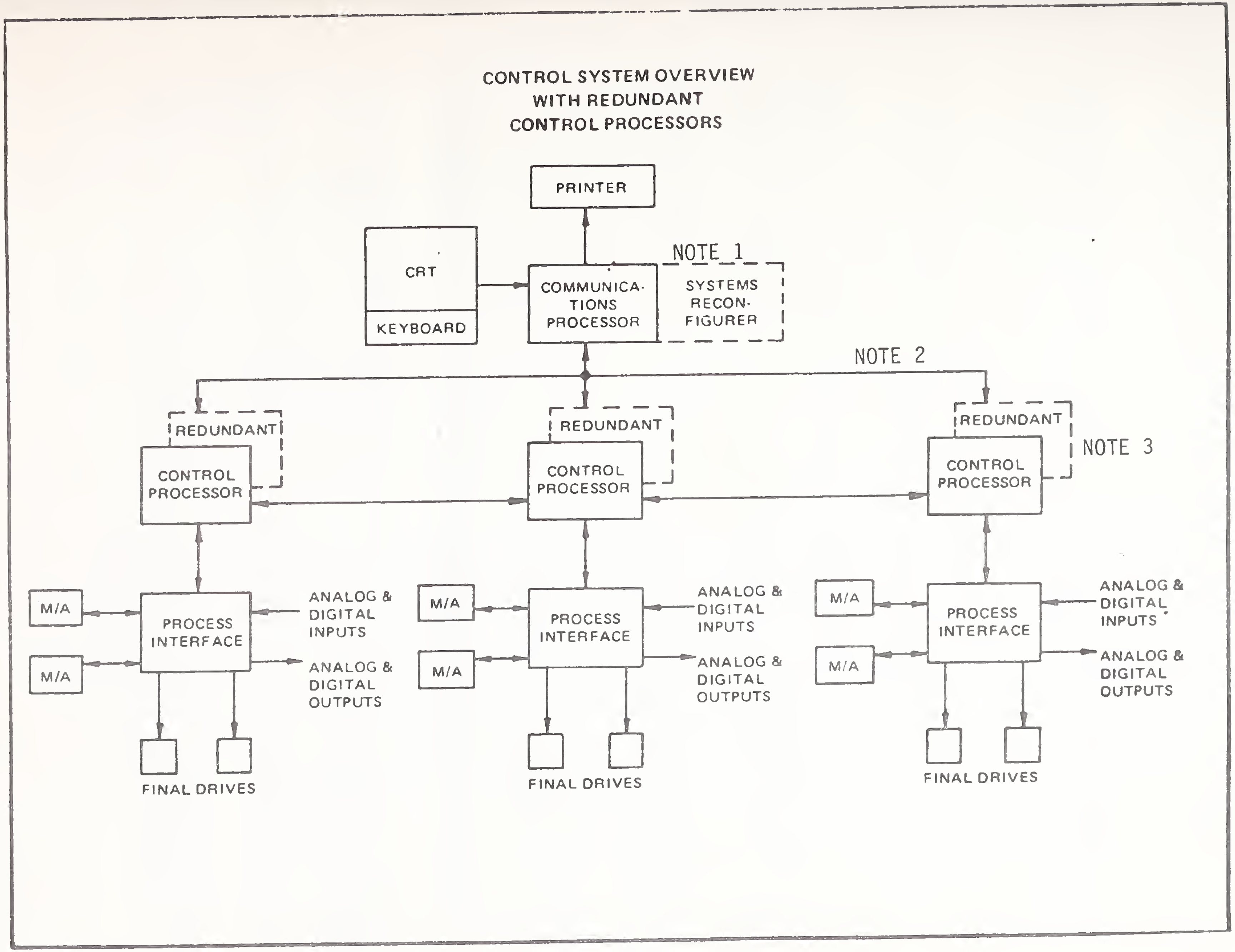
Several modes of control will be needed in each of the two operating situations - MHD testing and utility-controlled power production. For initial MHD testing it will probably be necessary to operate the MHD plant in a stand-alone mode with the utility plant off-line. This will minimize the complexity of the system and yield the highest probability of a successful MHD test. In later test stages and during combined utility operation, it will be necessary to demonstrate combined plant controllability and MHD flexibility by operating the entire plant together. Thus, the needed operating modes include startup (cold, warm, and hot), baseload (emphasis on stability and detailed controllability), transient, shutdown, and emergency for either single plant (MHD or existing conventional) or both.

The multiple modes of control needed for the facility and its status as a test facility require a flexible control system. Ideally the control system should be capable of modification to implement new and/or better control schemes as a greater understanding is gained during testing. These modifications should not require major efforts.

A Distributed Digital System (DDS) will be used for instrumentation and control. Each process system or subsystem will be under the control of a local microprocessor. The microprocessor set points will be determined by a supervisory computer that can act automatically or under manual operator control. This type of system yields the degree of flexibility that is appropriate to a test facility. Control algorithms can be modified from the supervisory computer and downloaded to the local microprocessors to implement desired changes in system operation. See Figure 2-5 for a diagram of this control scheme.

The control scheme consists of a supervisory computer system with cathode ray tube (CRT), keyboard, and control panel interface to human operators and a high-speed communications link to the local systems control computers that have real-time control over their respective systems. The use of this high-speed, multiplexed link eliminates the need for large numbers of wires carrying individual signals and thus removes a constraint on control room position. Since the supervisory computer control system does not need to be near the MHD plant that it controls, it can, and should, be placed in the existing Corette control room.

The local microcomputers perform the detailed control of their processes with only overall direction from the supervisory computer. The local microcomputers handle all raw data from sensors and send along to the supervisory computer only that data which is needed for the overall control function (including feedback to show the completion of commands; e.g., valve position sensor data.) The supervisory computer will maintain a



Notes:
1. Supervisory computer
2. High speed data communications link
3. Local microcomputers, one for each system

Source: Westinghouse Microprocessor Control System Literature

Figure 2-5

sequence-of-events log for analysis of cause and effect relationships resulting in alarm conditions. Redundant computers will be used for protection and to increase on-line reliability and ease of repair.

The eleven MHD processes that are under the control of the supervisory computer are detailed below and listed in Table 2-4.

Table 2-4

MHD PROCESS CONTROL REQUIREMENTS

ITEM	JUNCTION
Supervisory Computer	Controls local subsystem microcomputers and interacts with plant operator.
Primary Oxidizer Flow Control Microcomputer	Local, real-time control of all primary oxidizer system components; feedback to supervisory computer (SC) as appropriate.
Coal Flow Control Microcomputer	Local, real-time control of all coal handling and feeding system components; feedback to SC as appropriate.
Combustor and Channel Microcomputer	Feedback to SC as appropriate for determining combustor and channel operating conditions.
Superconducting Magnet Control Microcomputer	Local, real-time control of magnet and its associated cryogenic and electrical systems; feedback to SC as appropriate.
Flow Train Heat Removal Microcomputer	Feedback to SC as appropriate for determining heat transfer and flow train status.
Secondary Air Flows and Recirculation Gas Control Microcomputer	Local, real-time control of secondary air flow, recirculation gas and temperature; feedback to SC as appropriate.

Table 2-4

MHD PROCESS CONTROL REQUIREMENTS

(Cont'd)

ITEM	JUNCTION
Steam Generation Control Microcomputer	Local, real-time control of HRSR boiler feedwater flow and chemistry; feedback to SC as appropriate.
MHD Inverter Control Microcomputer	Local, real-time control of MHD Inverter; feedback to SC as appropriate. This control microcomputer is supplied by the Inverter manufacturer.
Protective Equipment Microcomputer	Monitor protective systems and sensors; feedback to SC as appropriate.

2.1.7.1 Primary Oxidizer Flow

The ASU, ASU compressor, blend air compressor, and mixer are all included here. The ASU will be self-contained and only its operating point will be controlled by the DDS. The primary controls on oxidizer flow will be the specified thermal heat rate and the specified stoichiometry.

2.1.7.2 Coal Flow

The entire coal feeding system including delivery, crushing, drying, lock hopper operation, and transport to the combustor will be included here. An accurate measurement of coal flow rate is desired and is very important to proper combustor operation and special attention will be given to installing measurement equipment adequate to that task. The primary control on coal flow rate will be the specified thermal heat rate. For accurate control of

combustion characteristics and slag handling an on-line coal analysis instrument will be used.

2.1.7.3 Combustor

Flame temperature and cooling water heat extraction will be monitored to determine combustor performance parameters. The supervisory computer will use these measurements in adjusting oxidizer and coal feed rates.

2.1.7.4 MHD Channel

No direct control is exerted over the channel, but measured parameters -- voltage and currents at selected electrodes, conductivity, power output -- are used in feedback loops to the combustor feeds and superconducting magnet.

2.1.7.5 Superconducting Magnet

The magnet and its associated cryogenic and electrical systems will be controlled together. The helium liquefied subsystem is self-contained and will be controlled by a Helium-demand signal.

2.1.7.6 Flow Train Heat Removal

Heat transfer from each component -- combustor, nozzle, channel, diffuser -- will be measured and used to assess wall properties such as slag layer thickness and metallic wall thickness. Changes in wall heat transfer can signal impending wall breakdown or excessive slag buildup.

2.1.7.7 Secondary Air Flow

The secondary air blower and heat exchanger will be controlled to produce the desired secondary combustion as determined by oxygen measurement in the stack. The secondary air preheat will be controlled by adjustment of hot exit gas flow to the secondary air heat exchanger.

2.1.7.8 Recirculation Gas

Economizer exhaust gas will be recirculated to the radiant furnace to aid in NO_x control. This gas stream will be controlled by blower speed based on achieving the desired temperature in the secondary combustion.

2.1.7.9 Steam Generation

Feedwater and reheat steam to the boiler will be controlled by flow control valves to regulate the amount of steam produced. Control of the valves will be done by sensing the ratio of the steam flow between the two boilers. Coal feed rates will also be controlled as necessary to maintain energy balance with steam produced. Feedwater chemistry will be adjusted as necessary to produce the needed water quality in the boiler.

2.1.7.10 MHD Inverter

The inverter is a self-contained system that will be operated under the control of the supervisory computer. Power input and output and cooling water temperature will be monitored by the supervisory computer.

2.1.7.11 Protective Equipment

Many of the MHD systems will have auxiliary sensors for protective purposes. These protective systems will be interfaced to the supervisory computer and appropriate, automatic, action will be taken in the event of a system breakdown. For example, if the channel integrity monitoring system reports a rupture of the channel wall, the combustor will be shut down on an emergency basis.

2.1.8 Data Acquisition

The data acquisition function will be handled by the same system that operates the instrumentation and control system. MHD performance parameters (electrode voltages and currents), power levels, heat balance, and input feed rates will be recorded for later analysis. Other parameters can also be recorded as it is determined they are required for system analysis.

The data acquisition system must be capable of taking and storing the data at rates sufficient to allow analysis and interpretation of events in the MHD power train. Some data will have to be recorded at frequencies in the kilohertz range. Table 2-5 lists the points to be monitored in each system. The system will be capable of expansion and will receive other data inputs than those mentioned.

TABLE 2-5

POINTS MONITORED BY DATA ACQUISITION COMPUTER

System	Parameter	# Of Places	Frequency (Hz)
ASU Control	Control System Interface	2-10	1
	Flow Rates	2-6	1
	Pressure	2-6	1
	Temperature	6-10	1
Blend Air Compressor	Motor Speed	1	1
	Lubrication Flow	1-5	1
	Lubrication Temp.	1-5	1
Oxidant Mixer	Valve Position	1-5	10
	Flowrates	1-5	10
	O_2 Concentration	1	1
Coal Flow	Flowrates	2-5	10
	Delivery Pressure	2-5	1
	Dryer Temp.	2	1
	Valve Position	1-6	10
	Coal Ash %	1	1
	Coal C/H Ratio	1	1
Combustor	Flame Temp.	1	100
	Cooling Water Temp.	2	1
	Pressure	2	100
MHD Channel	Cooling Water Temp.	4	1
	Electrode Voltage	30-40	1000
	Electrode Current	30-40	1000
	Power Output	1	10
	Pressure	20	1
	Pressure	2	100
Superconducting Magnet	Magnet Temp.	10-100	1
	Magnetic Field Level	10-20	1
	Current	1-10	1
Electric Power Supply	Voltage	1	10
	Current	1	10
Helium Liquefaction System	Pressure	5-15	1
	Temperature	5-15	1
	Helium flow	2	1

TABLE 2-5

POINTS MONITORED BY DATA ACQUISITION COMPUTER (Contd')

System	Parameter	# Of Places	Frequency (Hz)
Flow Train Heat Heat Removal	Water Flow	3-10	1
	Water Temp.	3-10	1
Seed Flow	Flow Rates	3	1
Secondary Air Flow	Air Flow	2	1
	Air Temp.	1-3	1
	O_2 Level	1	1
Blower	Lube Oil Temp.	1-5	1
	Lube Oil Flow	1-5	1
	Speed	1	1
HRSR	Water Flow	2	1
	Valve Position	2-10	1
	Water Chemistry	3-8	1
	Pressure	10-15	1
	Temperature	15-25	1
MHD Inverter	Power Input	1	10
	Power Output	1	1000
	Water Flow	1	1
	Water Temp.	2	1
Protective Equipment	TBD	TBD (100)	TBD
Corette Plant	Electric Power	1	1
	Steam Flow	2	1
	Coal Flow	1	1
	Pressure	5	1
	Temperature	5	1

2.2 MHD Interface Systems

2.2.1 Coal Preparation and Feed

To provide a consistent feed to the CFC there is a requirement to provide a uniformly pulverized coal with a maximum moisture content of 5%. Both raw received coal storage and prepared coal storage are required to support the various operational modes of the coal preparation system. An inerting atmosphere is necessary to prevent spontaneous combustion of the coal during the drying process. Separate discharge pipes on storage bins and the injection transport vessels are required to empty bins during operational problems. A method of weighing will be required; and a method of injecting the coal into the CFC will also be required to overcome the expected pressures. A system independent of the Corette plant is required for coal drying, pulverizing, and injection. Any atmospheric discharges must meet existing environmental air quality standards. Table 2-6 is a summary of the properties of Montana Rosebud subbituminous coal as used at the DOE Chemical Equilibrium Workshop in September 1979 and adapted for this study.

2.2.1.1 Storage and Predrying

Two additional coal storage bunkers would be constructed at the northern end of the ATS facility. A new transfer point would be constructed at the existing coal reclaim system by No. 5 coal conveyor to provide raw coal feed to the bunkers. This concept would take advantage of the existing coal handling and reclaim system which was initially designed to handle two units similar in size to the Corette plant. Although the layouts show the interface transfer point at the coal reclaim tunnel, an optional transfer

TABLE 2-6

MONTANA ROSEBUD SUBBITUMINOUS COAL

	Nominal Values	Range of Values
Ultimate Analysis % Moisture Free		
Hydrogen	4.6	2.8 - 6.4
Carbon	65.6	61.8 - 69.4
Nitrogen	1.0	0.9 - 1.1
Oxygen	14.4	12.4 - 16.4
Sulfur	1.1	0.4 - 5.0
Ash	13.0	6.0 - 17.0
Ash Analysis, %		
SiO_2	47.5	22 - 55
Al_2O_3	21.1	12 - 25
CaO	14.4	5 - 20
Fe_2O_3	7.8	2 - 20
MgO	4.6	2.2 - 7.0
TiO_2	0.8	0.2 - 1.4
K_2O	0.7	0 - 1.5
Na_2O	0.4	0 - 1.2
P_2O_5	0.4	0.1 - 0.7
Proximate Analysis, Moisture Free		
Volatile	37.7	34 - 42
Fixed Carbon	47.6	43 - 52
Moisture, as Received, %	25.5	20 - 35
Heating Value		
Dry BTU/lb	11,300	10,650 - 11,950
Fusions		
Initial Deformation Temp, °F	2244	1960 - 2420
Softening Temp, °F	2278	1990 - 2470
Fluid Temp, °F	2362	2040 - 2520

point could be located along No. 5 coal conveyor. Figure 2-6 identifies the primary equipment that will be required in the coal preparation system. Table 2-7 summarizes the major equipment capacities and flow characteristics.

A coal feeder would meter the raw coal from the coal bunkers to the crusher where the coal is reduced to 1/2" maximum size and fed into the coal predryer. The coal predryer reduces the nominal moisture of the Montana Rosebud subbituminous coal from 25.5% to 12% using a self-contained coal pulverizer and firing system for air drying. Preheated nitrogen will be used to temper the air back down to drying temperatures. That nitrogen gas will be as received from the air separation plant after exiting the nitrogen heater in the air leg backpass of the HRSR. The exhaust from the coal predryer is routed through a baghouse system to remove particulates.

2.2.1.2 Pulverizing and Drying

The predryed coal will be transported by enclosed conveyor to pulverizers where the coal will be pulverized to a grind size of 70% through 200 mesh with completion of drying to 5% moisture. Two pulverizers will be required to provide adequate allowances for repair or breakdown of those units and to enable continued operation of the MHD power train. Optionally, one pulverizer could initially be installed with provisions (area, conveying, electrical, control, etc.) for the installation of a second pulverizer when continuous operating conditions warranted it.

The pulverizers will use an airsweep drying system integral with their design and operation. The air heater will also use a self-contained coal pulverizer and firing system to preheat the air introduced into the pulverizers. An

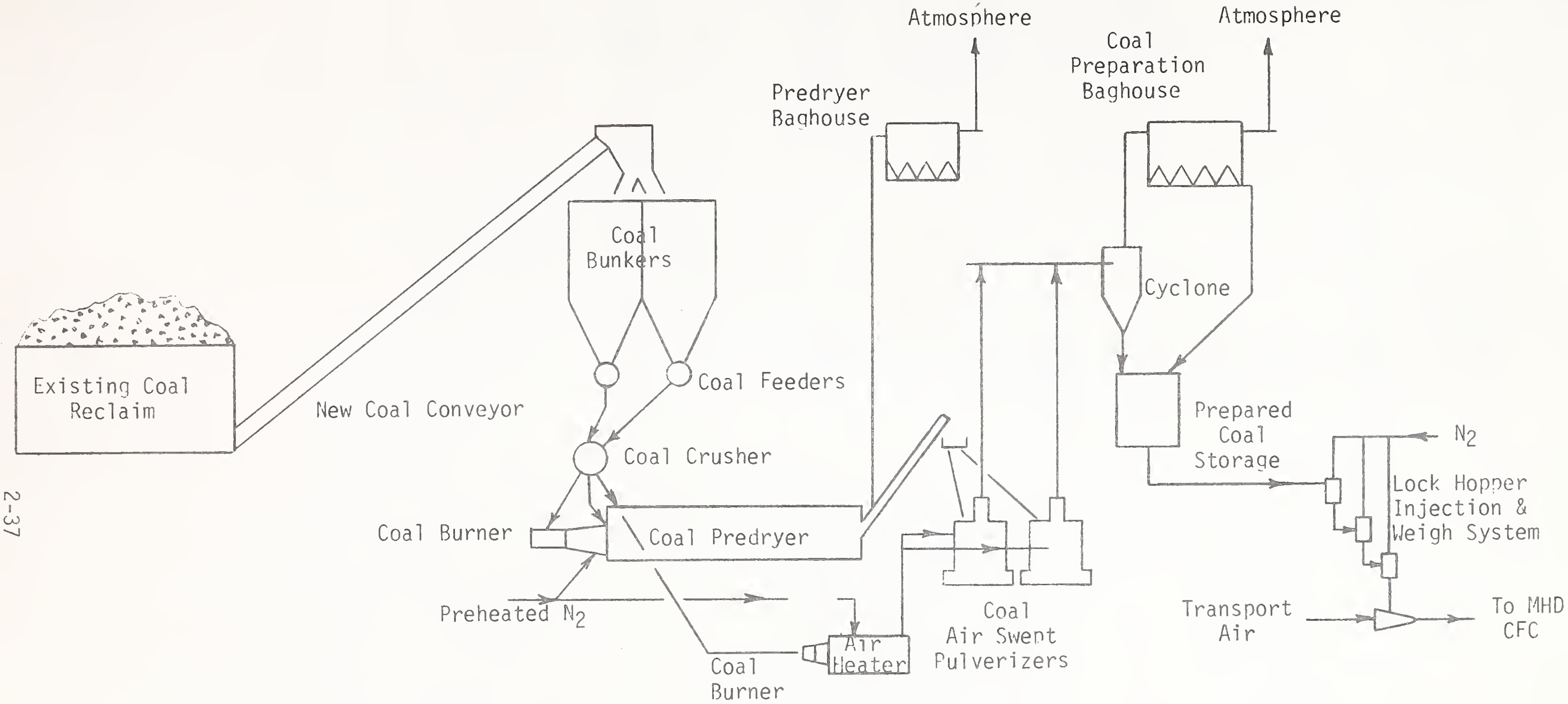


Figure 2-6 -- Coal Preparation & Feed System

TABLE 2-7

COAL STORAGE AND PREDRYING EQUIPMENT

ITEM	QUANTITY	CAPACITY (EACH)	NOMINAL OPERATING CONDITIONS
Coal Bunkers	2	400 Tons	
Coal Feeders	2	60 TPH	50.7 TPH (12.768 kg/s)
Coal Crusher	1	60 TPH	50.7 TPH (12.768 kg/s)
Coal Predryer with Nitrogen Tempering	1	60 TPH	Moisture Reduced From 25.5% to 12.0% 42.9 TPH (10.809 kg/s)
Air Swept Pulverizer with Air Preheater	1	50 TPH	Moisture Reduced From 12.0% to 5.0% 39.7 TPH (10.0128 kg/s)
Prepared Coal Storage Bin	1	40 Tons	39.7 TPH (10.0128 kg/s)
Injection System	1	45 TPH	39.7 TPH (10.0128 kg/s)

inerting atmosphere of nitrogen will be used to prevent spontaneous combustion of the coal as it is dried and transported throughout the coal preparation process. That nitrogen is also obtained from the air separation plant after it passes through the nitrogen heater in the HRSR. The nitrogen would have been exhausted to the atmosphere if it were not utilized in the coal preparation process. The coal preparation system is essentially an inert gas circulating/classifying system once the predried coal from the predryer is introduced into it. The coal should be dried to a constant BTU value to provide maximum stability in the coal-fired combustor, thereby providing a uniform plasma for MHD electrical generation.

As the dried pulverized coal entrained in the inert gas exits the pulverizer it is routed to a cyclone separator. The coal is directed to a prepared coal storage bin and the remaining gas with coal particulates continues to a baghouse where the coal fines are removed. The clean inert but moisture laden gas is vented to the atmosphere and the coal fines are transported to the prepared coal storage bin. The prepared coal storage bin is sized to provide only surge capacity requirements for temporary operational problems such as pulverizer feeder trips. The 40-ton capacity will also alleviate the requirements to leave the prepared coal storage bin empty during non-operation of the MHD power train.

2.2.1.3 Injection

Injection of the coal into the MHD combustor will require that its pressure be boosted to a pressure slightly above that of the combustor or approximately 6 atmospheres. A pressurized lock hopper system will provide a means to increase that delivery pressure to injection requirements. A

continuous weigh system will be incorporated into this system to provide an accurate and repeatable method of introducing coal into the MHD power train. This will be accomplished by using stepped pressure transport vessels with inter-connecting lock hoppers. The necessary stepping pressure requirements in the transport vessels will be provided by the use of nitrogen. A separate air compressor will be required to provide pneumatic transport of the prepared coal to the MHD combustor.

2.2.2 Seed

The design requirements for the seed system are to provide adequate bulk storage of dry seed material to provide a means of maintaining that dryness and to consistently inject a specified amount into the combustor. To prevent problems that may be encountered with agglomerated particles a hammer mill is needed to provide a uniform feed to a bulk weighing and transporting system.

Dry seed in the form of potassium carbonate (K_2CO_3) will be injected into the second stage of the combustor to provide adequate plasma conductivity in the channel for power production. This seed material will chemically combine with other elements in the plasma stream and will be removed in downstream sections of the HRSR or electrostatic precipitator. Seed reprocessing to recover the spent seed is not a part of the design requirements of the ATS.

2.2.2.1 Storage and Delivery

The seed will be received by railcar and unloaded directly to bulk seed storage bins. As the ATS has an excess of dry nitrogen at its disposal, a slight nitrogen pressure will be kept on the bulk storage bin to combat the

deliquescent nature of the seed. This will prevent agglomeration of seed particles into masses of wet lumps with the associated pluggage and handling problem. Feeders located at each seed storage bin will discharge to a hammer mill to provide a uniform product for injection to the MHD power train. A pneumatic conveying system will be used to convey the seed to a lock hopper vessel and primary injector vessel. A continuous weighing system will be incorporated in the pneumatic/feed system to provide the required amount of seed. The transport air compressor will be used for both coal and seed transporting to the CFC. Figure 2-7 identifies the major equipment in the seed system. Table 2-8 summarizes the equipment capacities and flow requirements.

2.2.2.2 Seed Recovery

The successful introduction of the seed material into the plasma stream depends on several factors such as composition of the gas, seed material, coal ash composition, mass and heat transfer, particle mechanics, thermochemistry, and condensation phenomena. Since there is a high chemical affinity of potassium to sulfur, the seed material will combine with the free sulfur in the combustion gases producing K_2SO_4 and providing an effective method of internal pollution control.

Eighty-five percent of the coal ash will be extracted in the combustor as slag and will be water quenched for disposal. The K_2CO_3 seed will be injected in the second stage of the combustor to prevent loss of seed in the slag during that combustion process. In the secondary portion of the heat recovery furnace seed material condenses prior to reaching the closely spaced tube sections. Collection hoppers and discharge mechanisms are appropriately located in areas of the furnace to enable bulk collection of material that

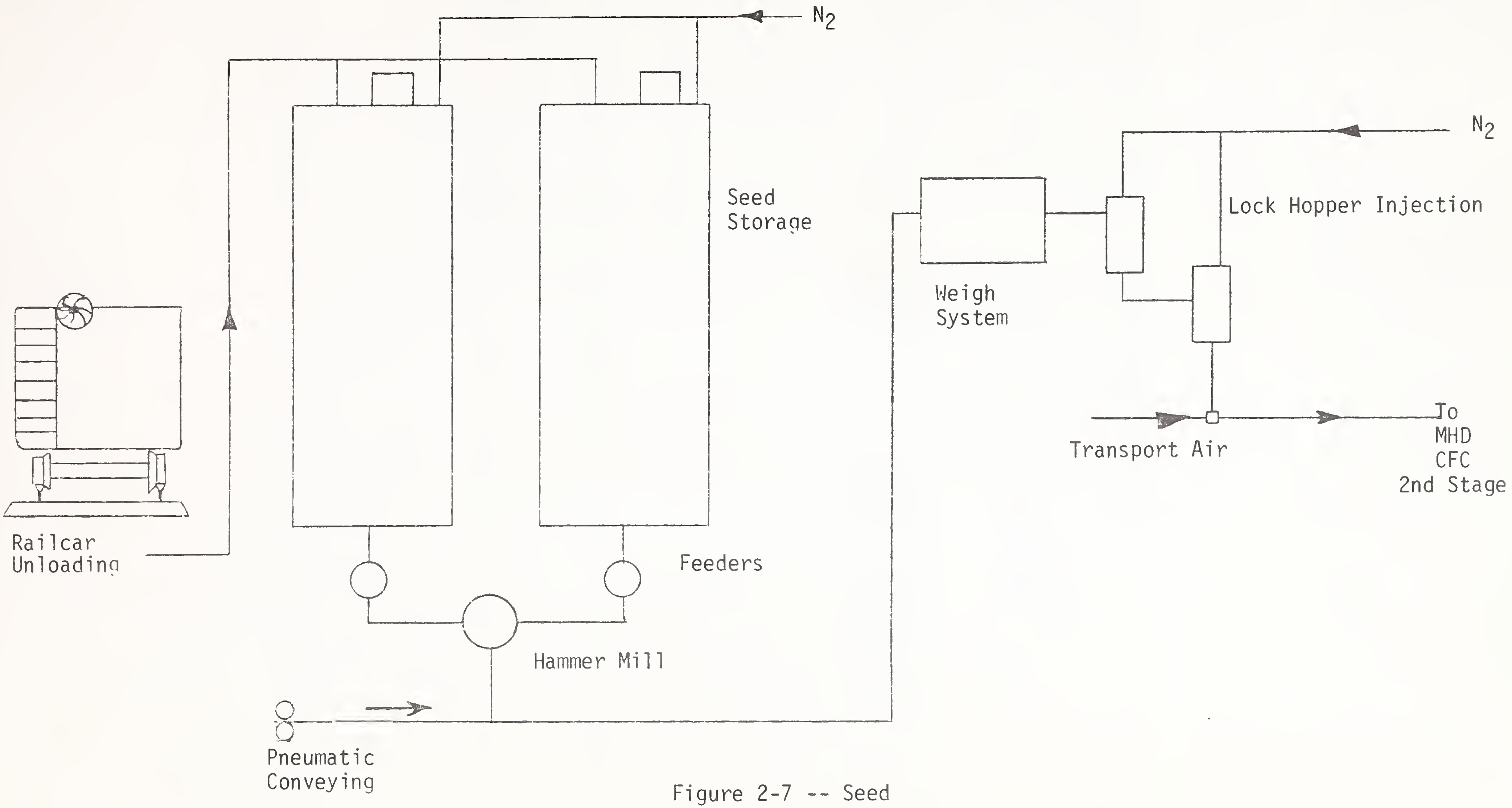


Figure 2-7 -- Seed

TABLE 2-8

SEED HANDLING

EQUIPMENT CAPACITIES AND FLOW REQUIREMENTS

ITEM	QUANTITY	CAPACITY (EACH)	NOMINAL OPERATING CONDITIONS
Rail Car Unloading	1	20 TPH	
Seed Storage Bin	2	500 Ton	
Feeders	2	5 TPH	3.93 TPH (0.9916 kg/s)
Hammer Mill	1	5 TPH	3.93 TPH (0.9916 kg/s)
Injection System	1	5 TPH	3.93 TPH (0.9916 kg/s)

is heavily laden with potassium related material (primarily K_2SO_4). The remainder of the collected material is fly ash with constituents related to the chemical composition of the coal.

2.2.2.3 Recovered Seed Disposition

Seed recovery and reprocessing will be an essential part of a commercial MHD plant in order to minimize operating costs. As the ultimate objective of this retrofit study is to demonstrate the integration of MHD and bottoming cycle components this section only addresses the recovery bottom ash and fly ash. Seed reprocessing of the bottom ash and fly ash was not considered mandatory to MHD operation, and would complicate initial operation of the plant. Although seed reprocessing has been described at length in several studies, a plant has not been built yet. Consequently, some risk is present to include a plant in the ATS; such a plant could be incorporated at some later date. The material that would be economical to reprocess will be stored for reprocessing in the future. Slag, bottom ash, and fly ash not economically feasible for further processing will be sold or disposed of in an environmentally safe manner. The reprocessing facility is a future consideration once the MHD facility operates consistently.

2.2.3 Oxidant

The oxidant supply system provides an oxygen enriched pressurized air to the MHD power train preheating system at the pressure and oxygen concentration specified. The present specifications are 366,355 lbm/hr (46.16 kg/sec) at 36 mole % oxygen with an injection pressure of 6

atmospheres. Figure 2-8 is a block diagram illustrating the basic oxidant supply system.

The major components of the system are the Air Separation Unit (ASU), Oxidant Mixing System, and Power Supply.

2.2.3.1 Air Separation Unit

Two companies were contacted for process recommendations to produce the oxidant supply required. Each was requested to design for the best economics, considering plant cost and energy consumption, coordinately with reliability of operation and minimizing redundancy.

Other requirements for the ASU are:

- Additional production of 10 TPD of liquid oxygen for tank storage of 20,000 gallon capacity to compensate for minor ASU maintenance shutdowns.
- Additional production of 10 TPD of liquid nitrogen for tank storage of 20,000 gallon capacity for use with the superconducting magnet refrigeration system.

Gaseous nitrogen for coal preparation is available at atmospheric pressure as a secondary product of the ASU. This nitrogen can be further utilized in the coal preparation plant and the superconducting magnet system.

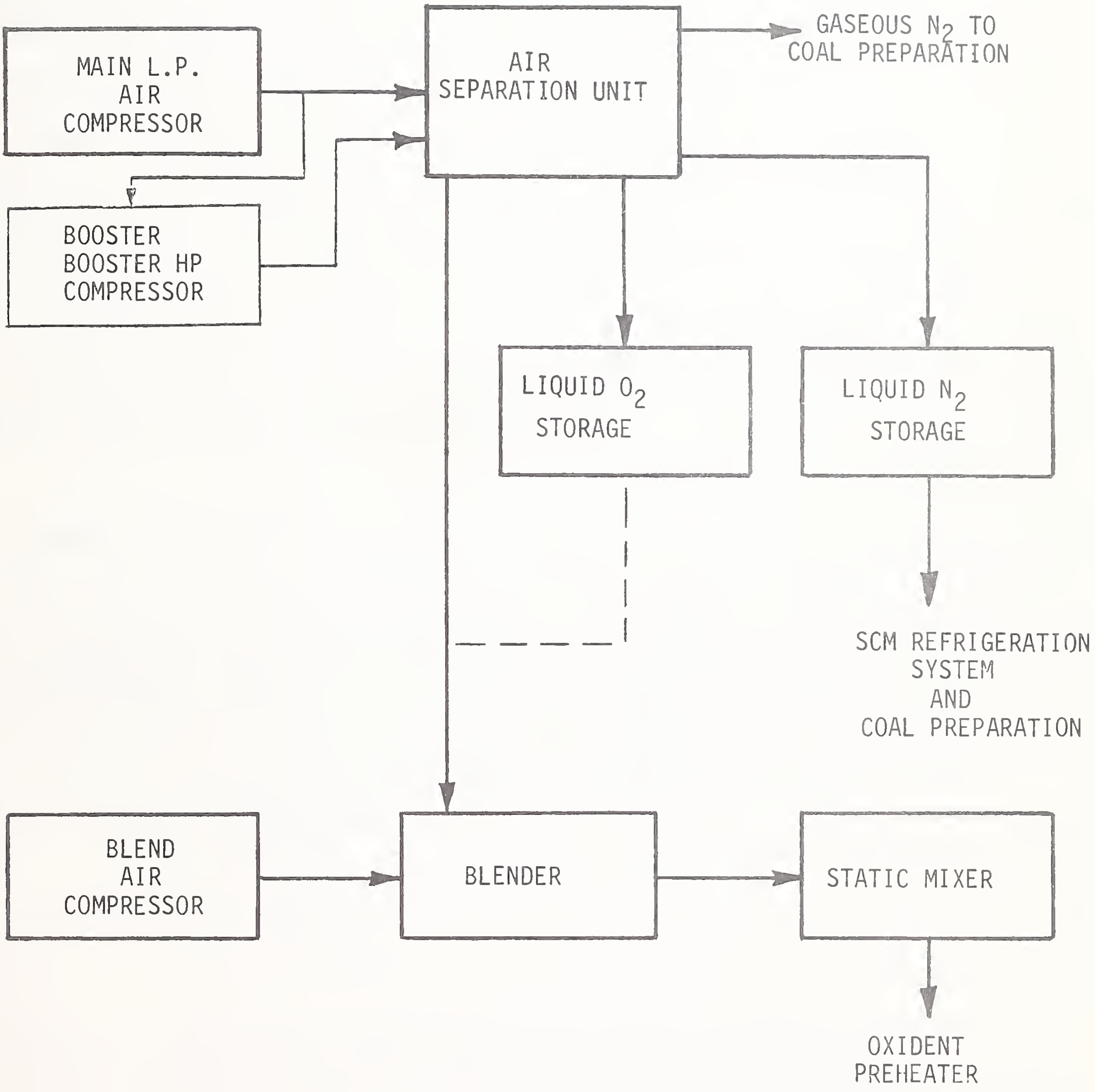


Figure 2-8 -- Oxidant Supply and Air Separation

Figure 2-9 illustrates one of the suppliers state-of-the-art process innovations currently developed, including pressurizing the product oxygen by pumping the liquid phase and vaporizing the liquid at pressure. The use of liquid phase pressurization produces the oxidant with the lowest overall specific energy. Liquid phase pressurizing pumps have been used in this country since the late 1930's on small air separation plants. During World War II hundreds of small plants were constructed employing reciprocating liquid pumps to fill aviator breathing oxygen cylinders. Beginning in the 1940's, centrifugal liquid oxygen pumps were employed on large tonnage oxygen plants. Reliability has been demonstrated to be at least equal to that of gas phase compression and reduced energy and capital costs have been achieved. Overall energy reduction is about 10%.

The air separation process as proposed by the second supplier and shown in Figure 2-10 differs from conventional plants in this country in that the oxygen is compressed outside the process plant. The gaseous oxygen is then mixed and compressed with the air in the oxidant compressor. This process approach has been the dominant design employed outside the United States and has a long history of reliability.

2.2.3.2 Oxidant Mixing System

Prior experience in continuous fluid mixing indicates that the best results are achieved by producing a uniform blend prior to entering the mixing chamber.

Continuous analyzer charts of fluids mixed continuously exhibit a sine-curve pattern. While the average concentration is achieved, regardless of the

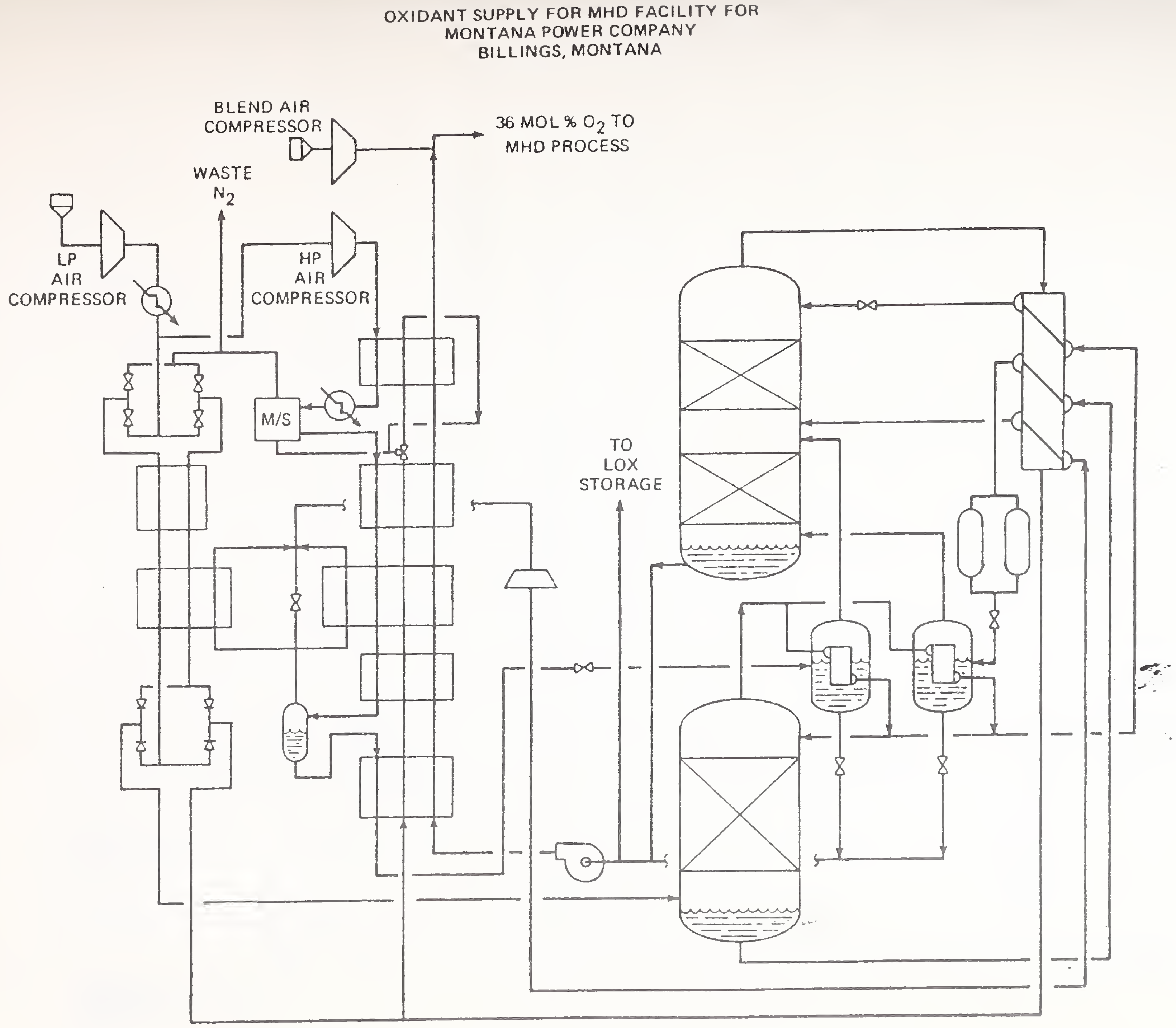


Figure 2-9 -- Oxidant Supply System - Typical Plant*

*Patented process of: Air Products & Chemicals, Inc.
Allentown, PA

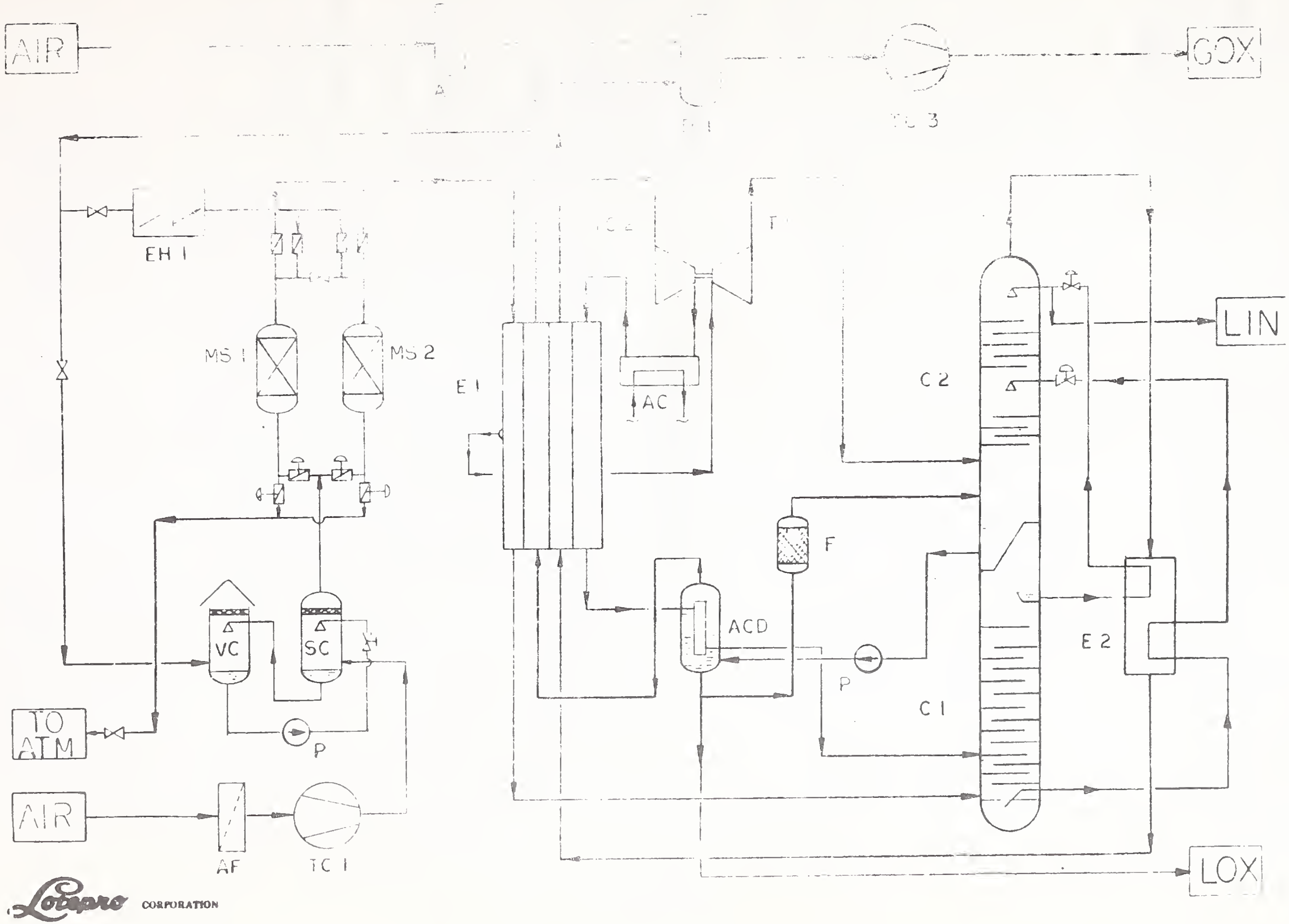


Figure 2-10 -- Air Separation Process

blending device, the amplitude of the "sine-curve" can be deleteriously large and effect the combustion characteristics. Blending with a simple piping-tee will produce the largest amplitude, while blending with a "Y" pipe fitting will be somewhat better.

The amplitude approaches a staight line when producing a blend with a vena-contracta section and that method is recommended to produce the oxidant mixture. The oxygen from the ASU is introduced at the low pressure point of the vena-contracta. An inline static mixer is then used to complete the mixing of the oxidant, as they require only about 1 psi pressure drop for complete mixing.

2.2.3.3 Power Supply

Since the Corette facility is adjacent to a major substation, electrical power for the air compressors was selected as the most reliable and least complex for operation versus steam turbine drives which could have impacts on the existing turbine condensing and feedwater system. Steam turbine drives could still be an option if the feedwater is modified in the retrofit. Three separate integral gear (four-poster) type compressors with two intercooled stages as shown in Figure 2-9 would be used to reduce shaft horsepower requirements. Those shaft horsepower requirements would be about 25000 BHP with an oxidant temperature of about 270°F.

It would be possible to recover more of the heat of compression into the oxidant product stream. However, this company believes that it would increase the compressor shaft power requirements by about 4000 BHP and

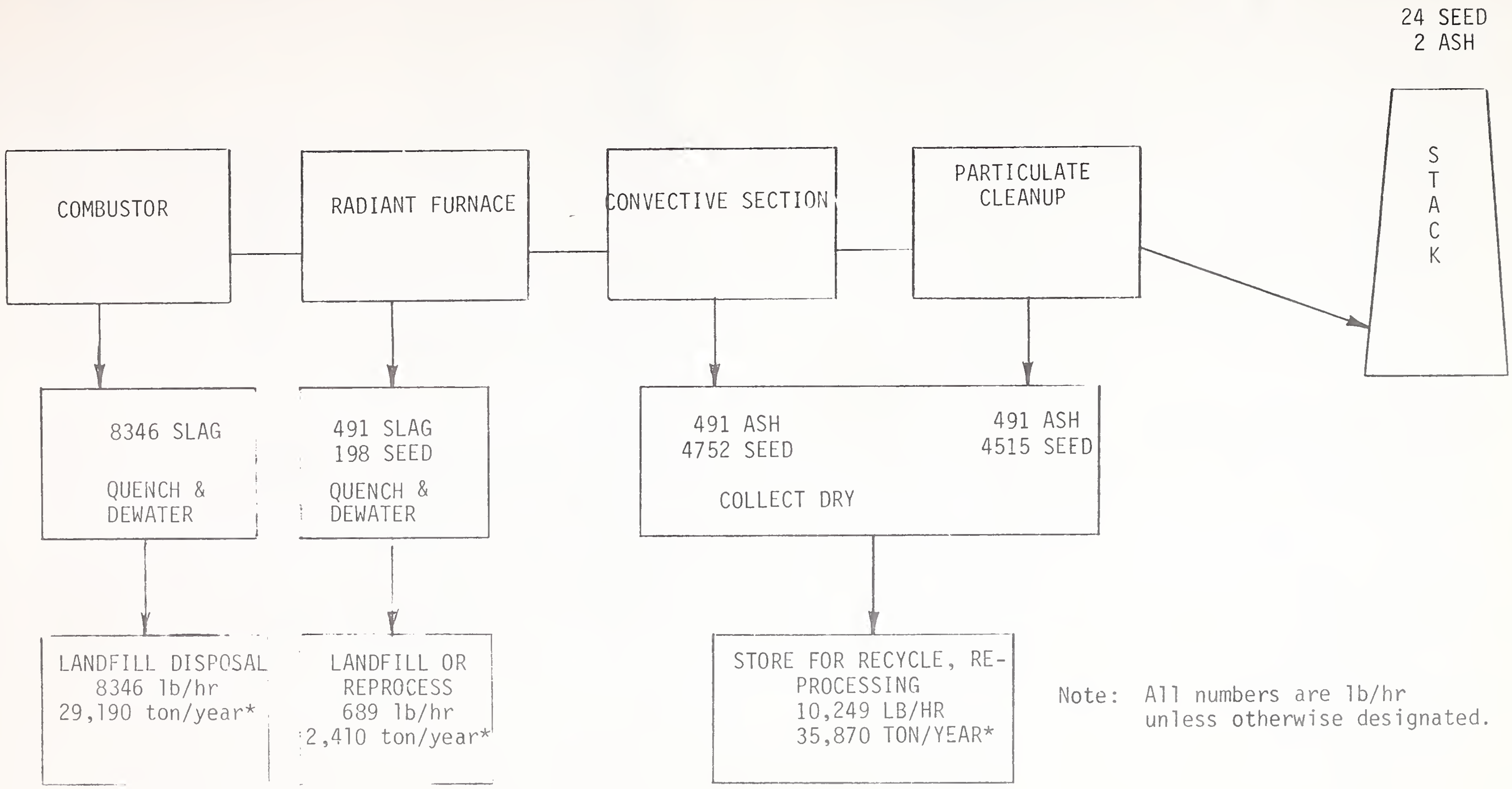
require non-standard, more expensive compressors. It is doubtful that the additional 200 to 300°F of oxidant temperature could justify this extra compression cost, for a plant of this size.

2.2.4 Effluent Handling

Ash and seed effluents are divided into three groups depending on the relative amounts of ash and seed in each stream as shown in Figure 2-11. The slag from the combustor will be collected in water quench tanks, dewatered and transported to a landfill or used for filler and building material. This material should be non-hazardous and 29,190 tons will be generated during an operating year of 7,000 hours as shown in Figure 2-11.

Slag from the radiant furnace may require quenching and dewatering separately from the combustor slag. Depending on the chemical and physical form of the seed material in this waste stream, it may require treatment to recover soluble potassium salts before disposal of the slag. If the seed is combined in the slag matrix in such a manner that subsequent testing shows it to be non-hazardous (as defined by RCRA) then these wastes can be handled in the same manner as combustor slag.

Seed and ash materials collected from the convective section and the particulate control device will be collected dry and transported off site for future reprocessing. These streams represent collection of nearly 98% of the seed material. For any long-term operation, it will be necessary to reprocess seed material from both operational economics and waste disposal viewpoints. Even if economically feasible, land disposal would not be allowed for the water soluble potassium compounds. During operation nearly



Note: All numbers are lb/hr unless otherwise designated.

Figure 2-11 -- Ash and Seed/Waste Recycle Streams

*Based on 7,000 hours of Operation

five tons per hour of potassium salts will be collected. A sealed storage facility sufficient to handle the spent seed at the rates indicated in Figure 2-11 will be required. One year's storage will require about 25 acre feet (equivalent to five acres, five feet deep). Nearly an equivalent amount of landfill must be available for disposal of slag.

2.2.5 Auxiliaries

Auxiliary systems are those MHD support systems that have a direct or secondary interface with the MHD power train or its auxiliary equipment. This section deals with water systems that are an integral part of the ATS, auxiliary fuels, compressed air and HVAC requirements.

2.2.5.1 Feedwater

The MHD and HRSR system requires feedwater of a similar quality to that used at the Corette plant to ensure protection of the heating surfaces and provide adequate steam quality. Methods to ensure adequate delivery of that feedwater under initial startup and normal operating conditions is required as well as providing the necessary subsystem for proper chemical control. The ATS will share the evaporator, condensate and feedwater system that is currently in use at the Corette plant. The interconnecting tie will be between the condenser and number five feedwater heater. A booster feedwater pump will be required to overcome the additional pipeline friction losses due to the more remote location of the heat recovery unit. There are also additional friction losses that have to be overcome in capturing heat from the first stage CFC and MHD diffuser cooling loops, the MHD channel cooling water system, and recirculation during startup operation.

The HRSR boiler fill and wash pump will also have its water supply from a condensate storage tank with makeup from the Corette condensate system. It will have an interchangeable spool to provide a second water source from the city water supply. A wash water circulating pump is included to provide adequate cleaning action for the various boiler headers.

The desuperheaters on the superheated and cold reheat steam receive their water supply directly from the booster feedwater pump to adequately control final steam temperatures with a high quality water supply.

To provide adequate chemical control of the HRSR boiler water a chemical feed system is required. The pump/makedown tank system will be similar to the existing units at Corette. To maintain proper water and steam chemistry, additions of phosphate, caustic, oxygen scavenger, and neutralizing amines are anticipated. A water sampling system would also be included as a means of analyzing the various parameters on feedwater, steam, and continuous blowdown. A blowdown control system will also be included as part of the sampling system. Figure 2-12 identifies the major components of the feedwater system.

2.2.5.2 MHD Channel Cooling Water

All interconnections between the MHD power train must be electrically isolated from support structures, piping, building steel, etc., due to the high electrical field generated around the combustor second stage and the MHD channel. The closed circulating cooling water loop for cooling of the combustor second stage and the MHD channel is within this highly charged field and will use condensate for electrical isolation. The cooling water

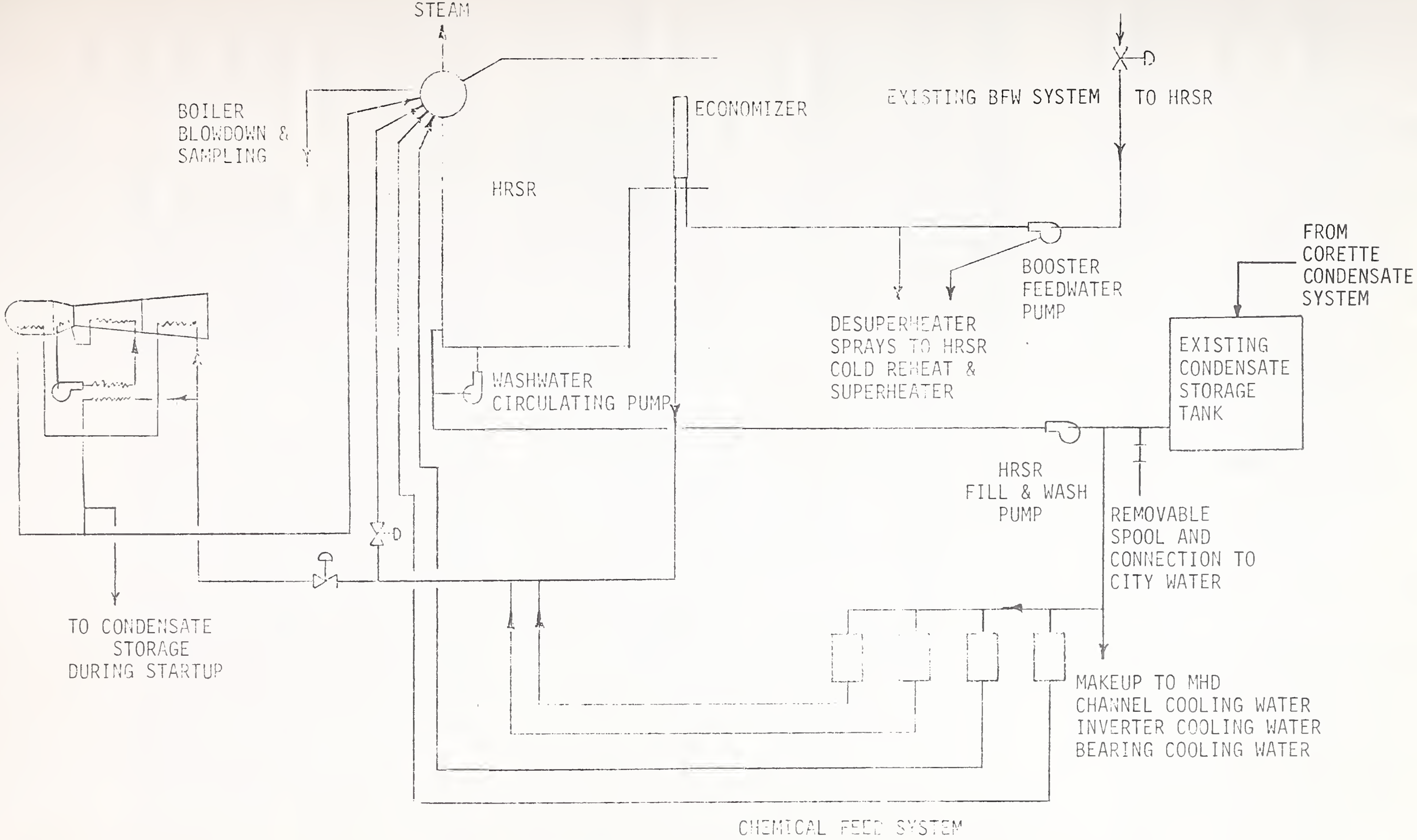

STEAM
BOILER BLOWDOWN & SAMPLING
HRSR
ECONOMIZER
EXISTING BFW SYSTEM
TO HRSR
BOOSTER FEEDWATER PUMP
DESUPERHEATER SPRAYS TO HRSR COLD REHEAT & SUPERHEATER
FROM CORETTE CONDENSATE SYSTEM
EXISTING CONDENSATE STORAGE TANK
WASHWATER CIRCULATING PUMP
HRSR FILL & WASH PUMP
REMOVABLE SPOOL AND CONNECTION TO CITY WATER
TO CONDENSATE STORAGE DURING STARTUP
MAKEUP TO MHD
CHANNEL COOLING WATER
INVERTER COOLING WATER
BEARING COOLING WATER
CHEMICAL FEED SYSTEM

Figure 2-12 -- Feedwater

will dissipate its heat to the boiler feedwater in a high efficiency plate type heat exchanger. A mixed bed demineralizer will be continuously used as a slip stream to retain the required water quality. Makeup water will be provided from the condensate storage tank. Provision is made to recirculate the feedwater back to condensate storage during startup conditions when normal boiler feedwater flow is low or non-existent. Figure 2-13 shows the major components of the system.

2.2.5.3 Inverter Cooling Water

The inverter will require cooling water to dissipate the thyristor heat load. A closed cooling water loop with circulating pump, cooling tower, and chemical feed system will be used to dissipate this low grade heat to the atmosphere instead of adding to the heat load being rejected to the Yellowstone River. Makeup will be from the condensate storage tank to assure water quality and minimize corrosion, scaling, and makeup requirements. Figure 2-14 identifies the major components of this system.

2.2.5.4 Service Water

A primary cooling water system utilizing Yellowstone River water is required to dissipate heat loads generated from mechanical equipment and lubrication oils. This system should be similar to the existing Corette plant circulating, service water, and screen wash system to provide a continuity of operations between the two plants. That existing Corette system will continue to supply the condenser cooling water for the turbine-generator and the Corette plant heating loads. The use of any existing intake structures on the Yellowstone River would reduce construction costs and simplify site layout.

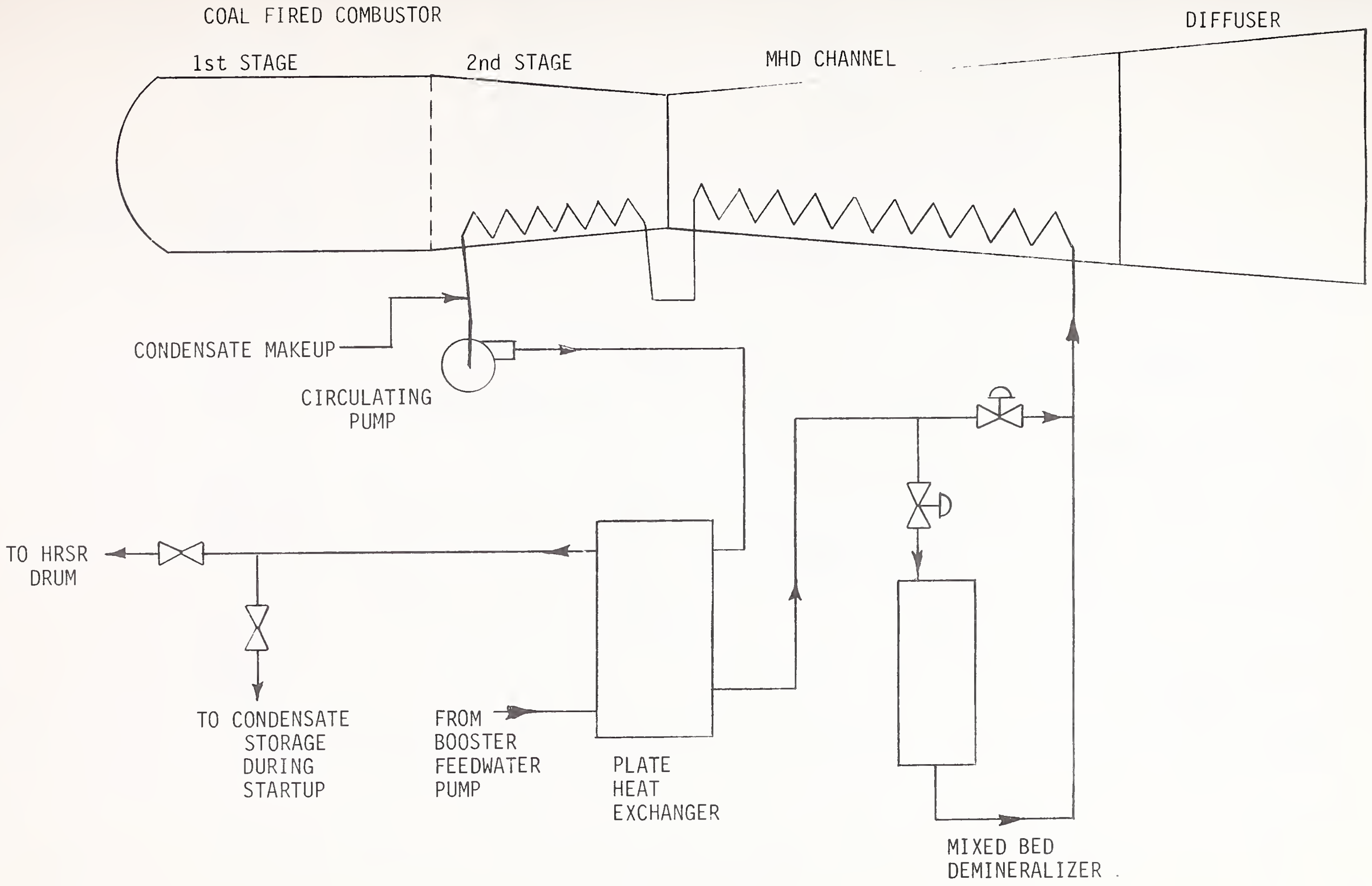


Figure 2-13 -- Channel Cooling Water

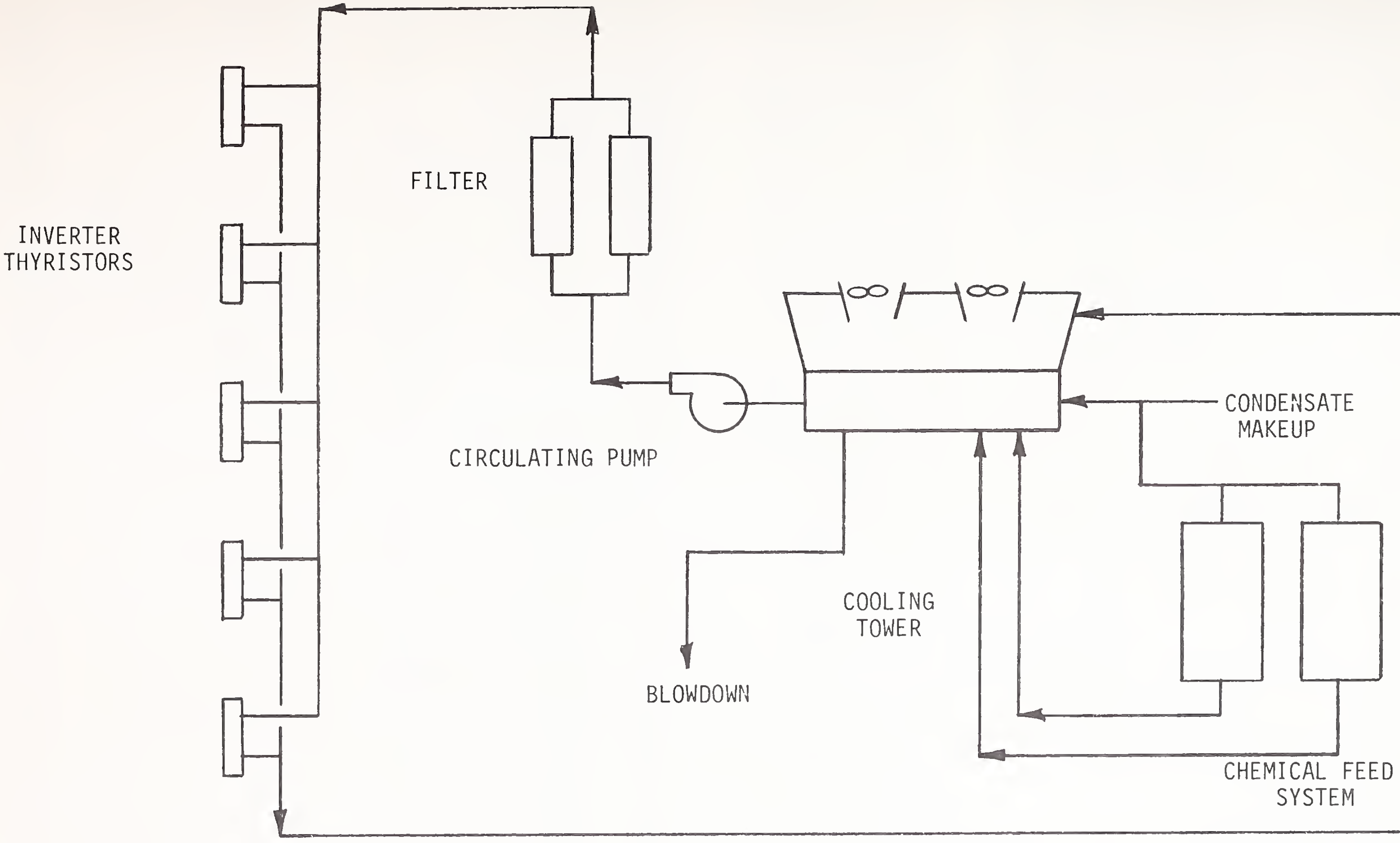


Figure 2-14 -- Inverter Cooling Water

A new service water pump will be installed at the Corette plant intake structure. This will take advantage of an available area on the existing intake structure at that location. The pump will provide a cooling water supply to the high efficiency plate type bearing cooling water heat exchangers, after which the service water will discharge through the existing Corette discharge structure. This discharge will have to be within the discharge flow and temperature requirements currently in effect at the plant and total flow must also not restrict the current Corette plant cooling requirements.

Makeup water requirements for the CFC slag handling system, HRSR bottom ash sluicing system, and the blow-off quench tank will come from this system as well as any requirements for floor wash down hoses. Figure 2.15 identifies the service water system components.

2.2.5.5 Bearing Cooling Water

A system will be required to provide a cooling water medium to offset heat loads generated from various mechanical equipment and their lubrication oils. The system should be similar to the existing Corette bearing cooling water system and provide cooling functions to similar items of equipment.

The bearing cooling water system will circulate water through high efficiency plate type bearing cooling water heat exchangers to serve a similar function as the existing bearing cooling water system. This bearing cooling water system will be capable of handling the cooling requirements on major equipment. That equipment would be items such as the feedwater booster pump, pulverizers, air separation plant refrigerant compressor, service air

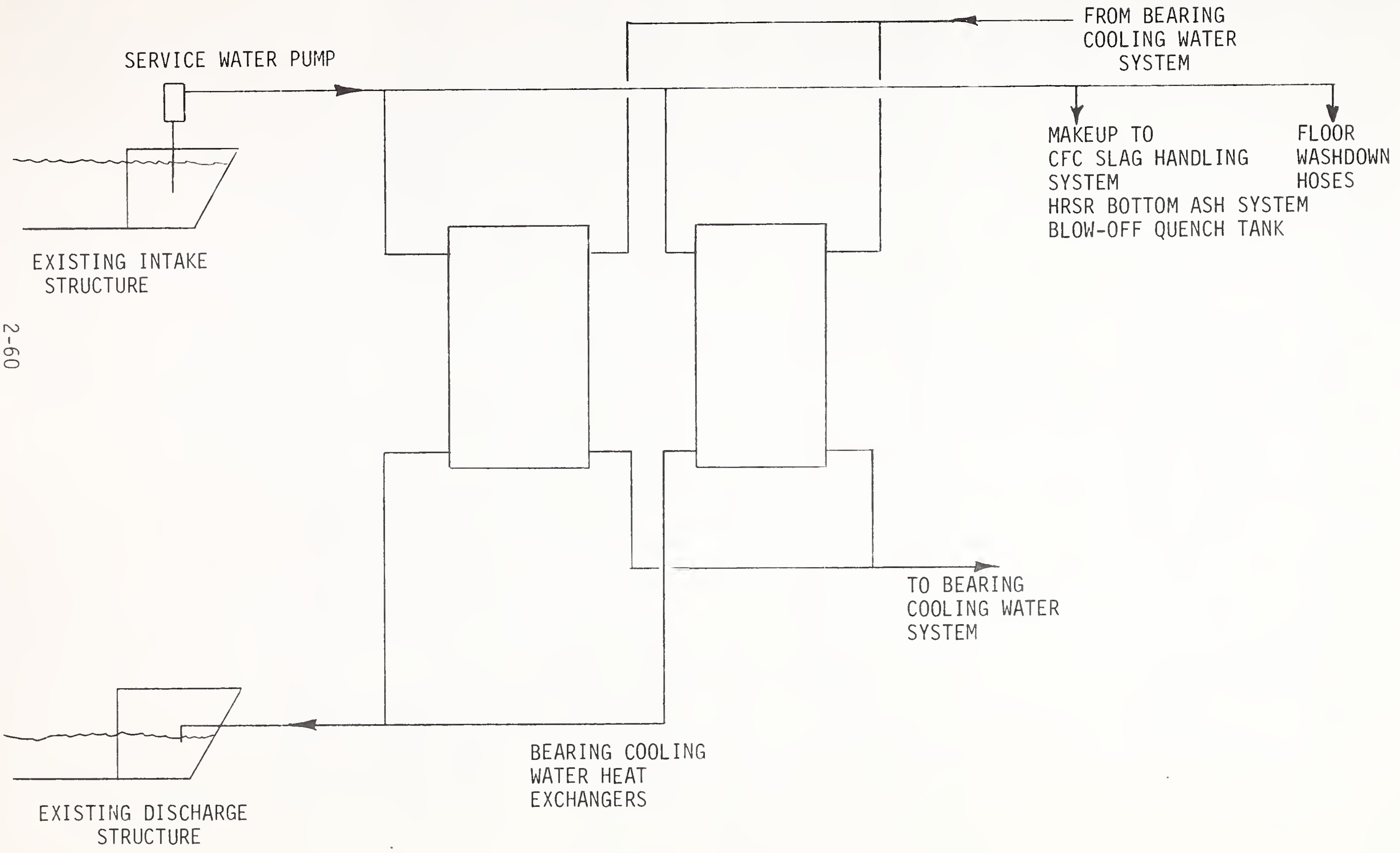

SERVICE WATER PUMP
EXISTING INTAKE STRUCTURE
EXISTING DISCHARGE STRUCTURE
FROM BEARING COOLING WATER SYSTEM
MAKEUP TO CFC SLAG HANDLING SYSTEM HRSR BOTTOM ASH SYSTEM BLOW-OFF QUENCH TANK
FLOOR WASHDOWN HOSES
TO BEARING COOLING WATER SYSTEM
BEARING COOLING WATER HEAT EXCHANGERS

Figure 2-15 -- Service Water

compressor jacket and aftercoolers, air dryer cooler, SCM subsystems, slag/ash grinder, injection air compressor, blend air compressor, Main L.P. air compressor, and the booster H.P. air compressor. Small systems requiring some recirculating cooling water such as sample coolers, instrument racks, etc., would also be on this system. Makeup will be from the condensate storage tank. Figure 2-16 identifies major components of the system and summarizes the usages.

2.2.5.6 Potable Water

A potable water supply is required for personnel use in the plant as well as a clean source of pump gland seal water. Pumps shall utilize mechanical seals as far as practical in the entire ATS facility to reduce water comsumption.

A potable water system break tank will be installed to provide potable water with a consistent head to the locker room, electric water coolers, pump gland seal water, and for inductor water to the oxygen/combustor analyzer. Analysis of the existing system is required to determine quantity and availability of the existing city water supply. A secondary water supply to the HRSR fill and wash pump can be obtained from the city water line by using an interchangeable spool from the normal condensate supply line. City water will be routed to the elevated break tank from the existing city water main. A meter will be included to determine the usage of the water source. Figure 2-17 provides an outline of the system and the water uses.

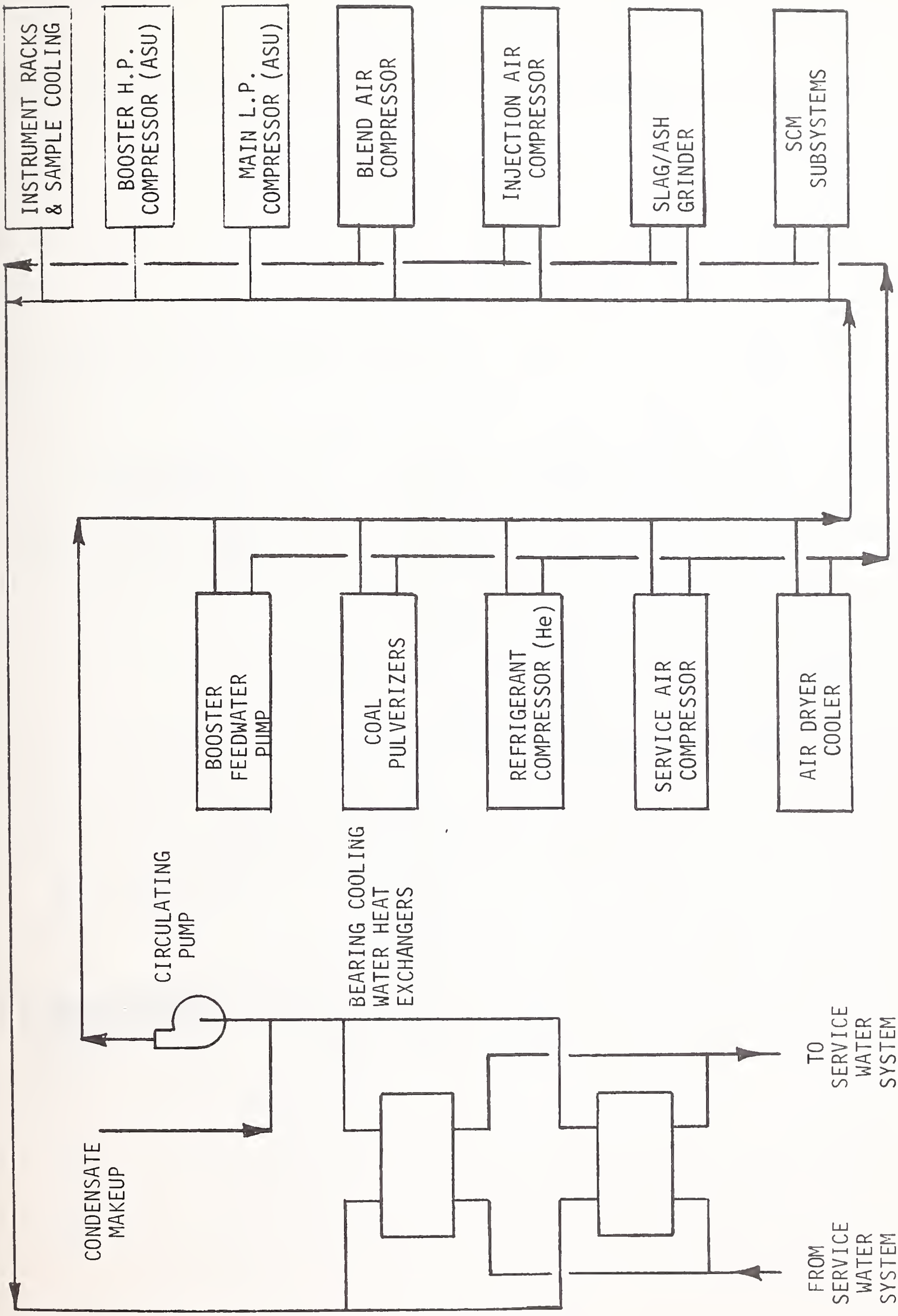


Figure 2-16 -- Bearing Cooling Water

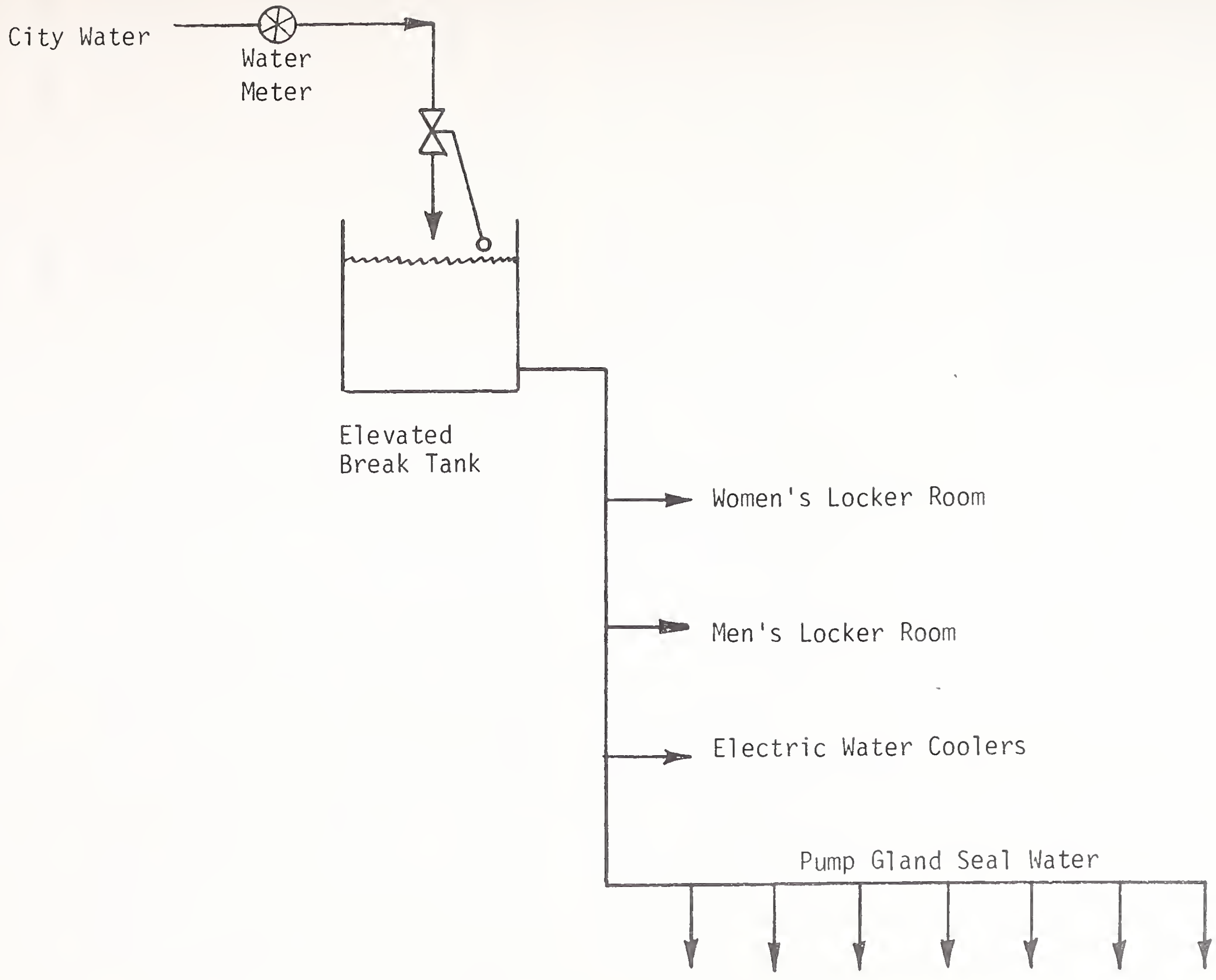


Figure 2-17 -- Potable Water

2.2.5.7 Fire Protection

Adequate fire protection is not only a requirement per regulatory agencies but also for plant insurance considerations. Design calculations will be required to ensure that the existing plant-wide fire system can be expanded to include fire loop perimeters around the new buildings and also provide sprinkler coverage inside as required by the NFPA. Fire extinguishers will be located at the appropriate locations in the facility. Figure 2-18 outlines a modified system to include the ATS.

2.2.5.8 Natural Gas

There is a fuel requirement for pilot ignition of coal in the coal predryer, pulverizer airheater and coal fired combustor at the ATS. In addition to that nominal requirement of fuel, the assumption was made that firing of an alternate fuel in the HRSR may be required for various operational modes.

The fuel requirement for pilot ignition of the coal predryer, pulverizer airheater, coal fired combustor and the potential firing of the HRSR during periods of non-MHD operation will be satisfied from the existing natural gas supply at the Corette plant site. Usage of natural gas is minimal with pilot ignition during startup times and virtually non-existent in normal operation. The use of warmup guns to bring the HRSR above ambient conditions during startup and before introduction of hot MHD plasma gases is anticipated. The provision for alternative firing of the HRSR is offered as an operational means to overcome abnormal conditions during shutdown, startup, and furnace recovery times. Figure 2-19 identifies the existing gas service and the new requirements.

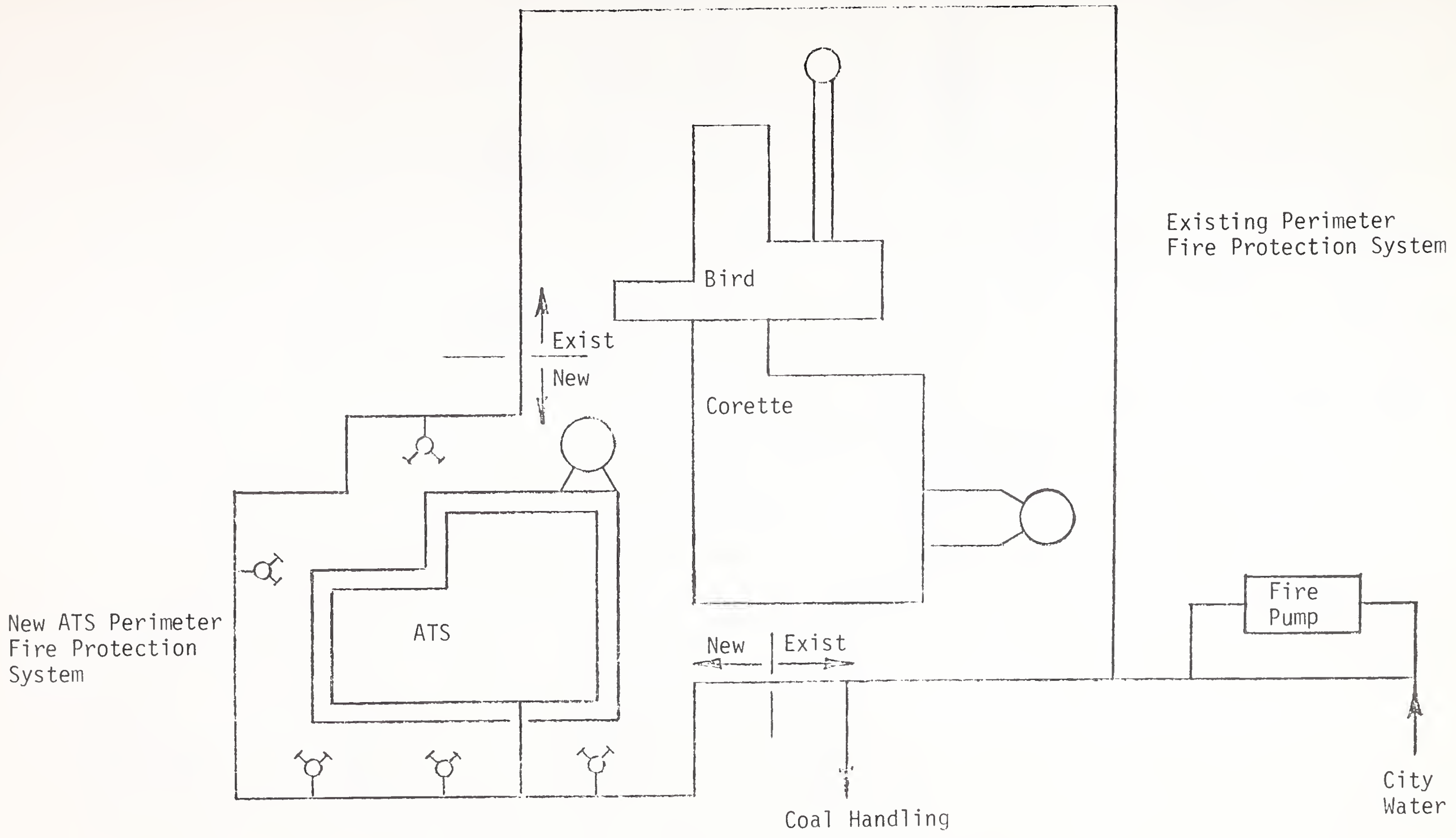


Figure 2-18 -- Fire Protection

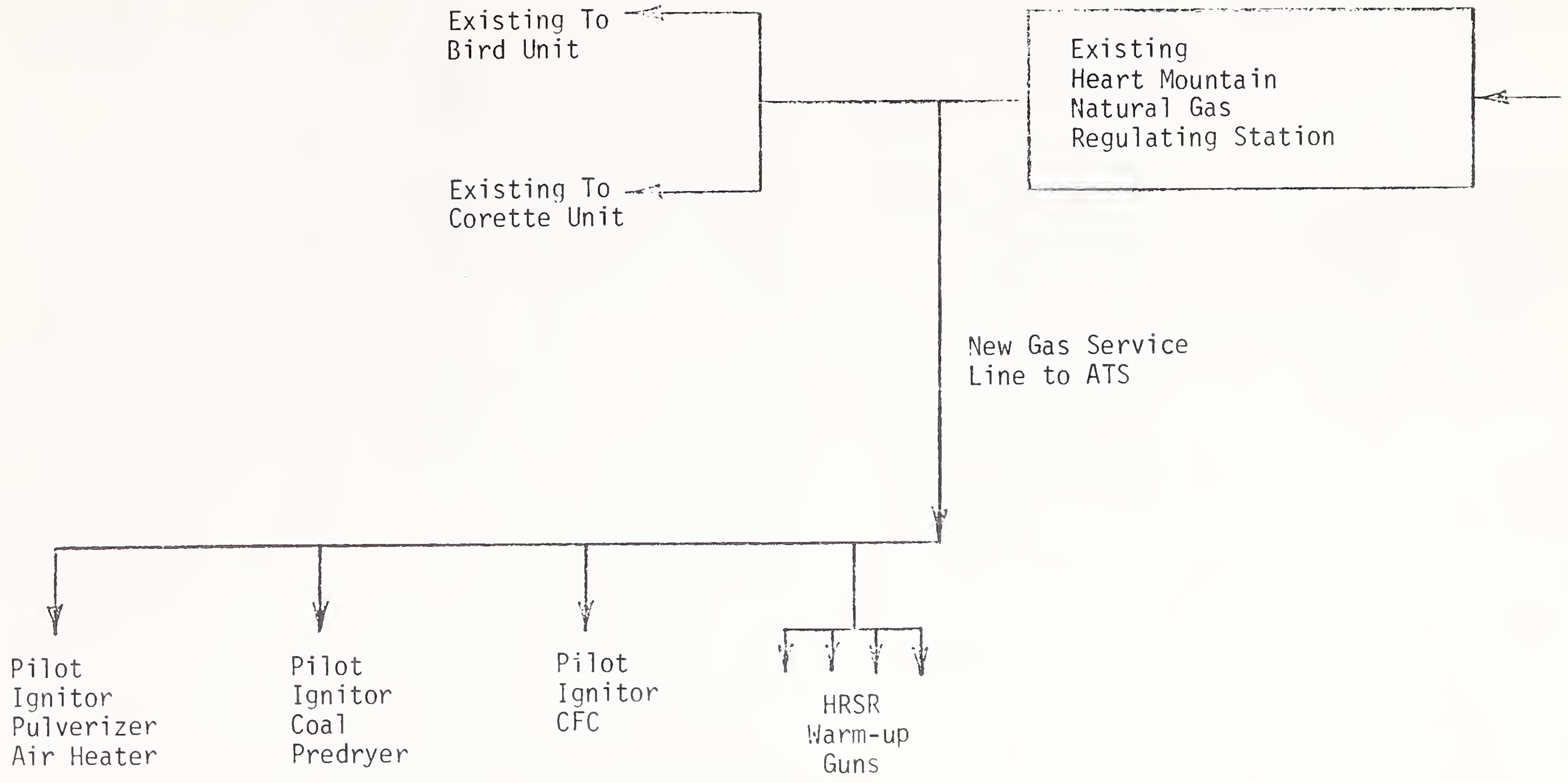


Figure 2-19 -- Natural Gas

2.2.5.9 Service and Instrument Air Compressor

A reliable source of plant service air will be required for general duties throughout the plant as well as some clean dry air for specific instrument requirements.

An analysis of total air requirements should be completed to assess whether one or two air compressors are needed. If instrument action is primarily electrically driven, soot blowers steam driven, and other air usage minimized, there would be minimal requirements for plant air usage and a single low-volume air compressor may be satisfactory.

A centrifugal type service and instrument air compressor will provide the quantities of service air during operation of the facility. A slip stream from the centrifugal air compressor or compressors will be routed through an air dryer to supply the moderate amounts of clean dry instrument air. Figure 2-20 identifies the major components of the system.

2.2.5.10 Heating, Ventilating and Air Conditioning

All of the plant building areas will require some method of heating, ventilating, or air conditioning per code and health requirements. Fresh air makeup, comfortable working conditions, temperature/humidity controlled environments, and freeze protection are prerequisites for the various heating and ventilating systems. An extension of the existing Corette 175 psig steam

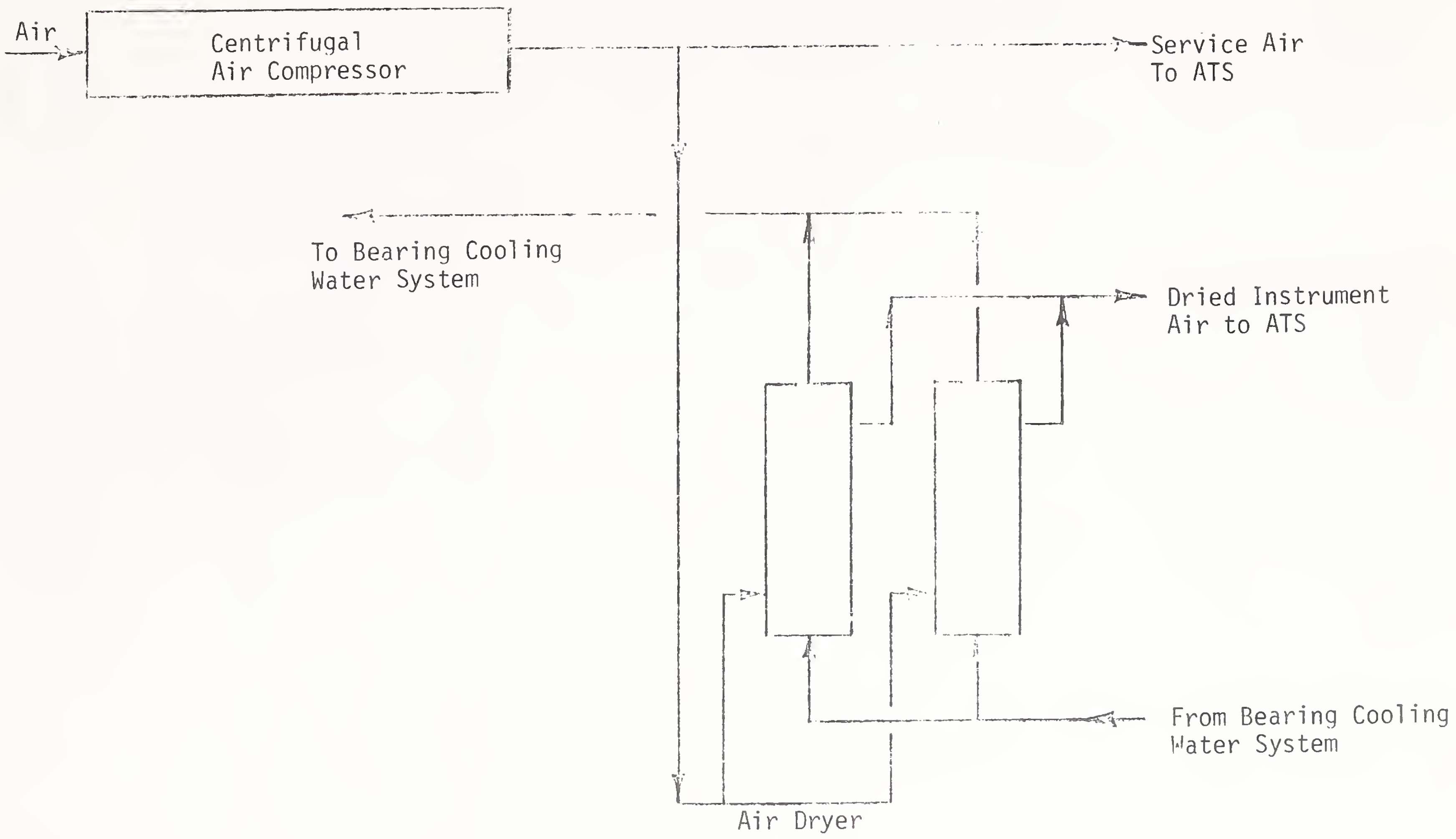

Air
Centrifugal Air Compressor
Service Air To ATS
To Bearing Cooling Water System
Dried Instrument Air to ATS
From Bearing Cooling Water System
Air Dryer

Figure 2-20 -- Service and Instrument Air

system will be used for the heating medium if that system is found to be adequate in size to supply both the existing plant and the new ATS facility. An alternate design would use electric resisting heating. Additional cooling and humidity controlled environments will be used in sensitive areas such as the control room, instrument room and the adjacent data acquisition system.

2.2.6 Particulate Control

The particulate control device is dictated by requirements for best available control technology (BACT) or lowest achievable emission rates (LAER) depending on specific permit requirements described in Section 3.2. For all practical purposes there is currently little difference between these two designations. BACT, LAER and the assumptions and uncertainties inherent in MHD combustion favor the selection of fabric filtration to achieve high collection efficiency over a possible wide range of particle size distributions.

One operating constraint is that temperatures must generally be controlled below 500°F for commonly used bag filter media. The plant material balance shows the collected particulates at this point in the process will be primarily potassium compounds since most of the ash is removed as slag at the combustor or the radiant furnace. This material will be collected dry and handled as described in Section 2.2.4.

A mimimum collection efficiency of 99.5% is required at the design collection rate of 5,000 lbm/hr. For design purposes, a 99.9% collection efficiency at 10,000 lbm/hr should be considered to allow for significant increases in ash or seed carryover from the upstream process. A trade-off between cost and

acceptable pressure drop and air/cloth ratio will be an integral part of the size selection process. A unit divided into separate sections sized so that operations could continue with one section out of service would also be desirable from a maintenance and reliability viewpoint.

An additional advantage of fabric filtration is that collected seed material coating the bags could result in additional SO_2 control by conversion of any unspent K_2CO_3 to K_2SO_4.

2.2.7 Substation and Transmission

The 25 KV AC output from the inverter will pass through a protective circuit breaker and be carried on underground cables capable of carrying 30 MW of power. The cables will feed the main transformer to step the voltage up to 100 KV so as to be compatible with the MPC's system at the nearby Billings Steam Plant/Substation. This will require a 100 KV transmission line approximately 600 ft in length and a protective circuit breaker where the transmission line meets the 100 KV station ring-bus. There will also be an auxiliary transformer to serve the motor loads and miscellaneous lighting. Figure 2-21 is a one-line diagram of the system.

The inverter output will pass through a 25 KV Sulphur Hexafluoride Gas (SF6) circuit breaker rated at 1200 amperes. This breaker will be located in the inverter building.

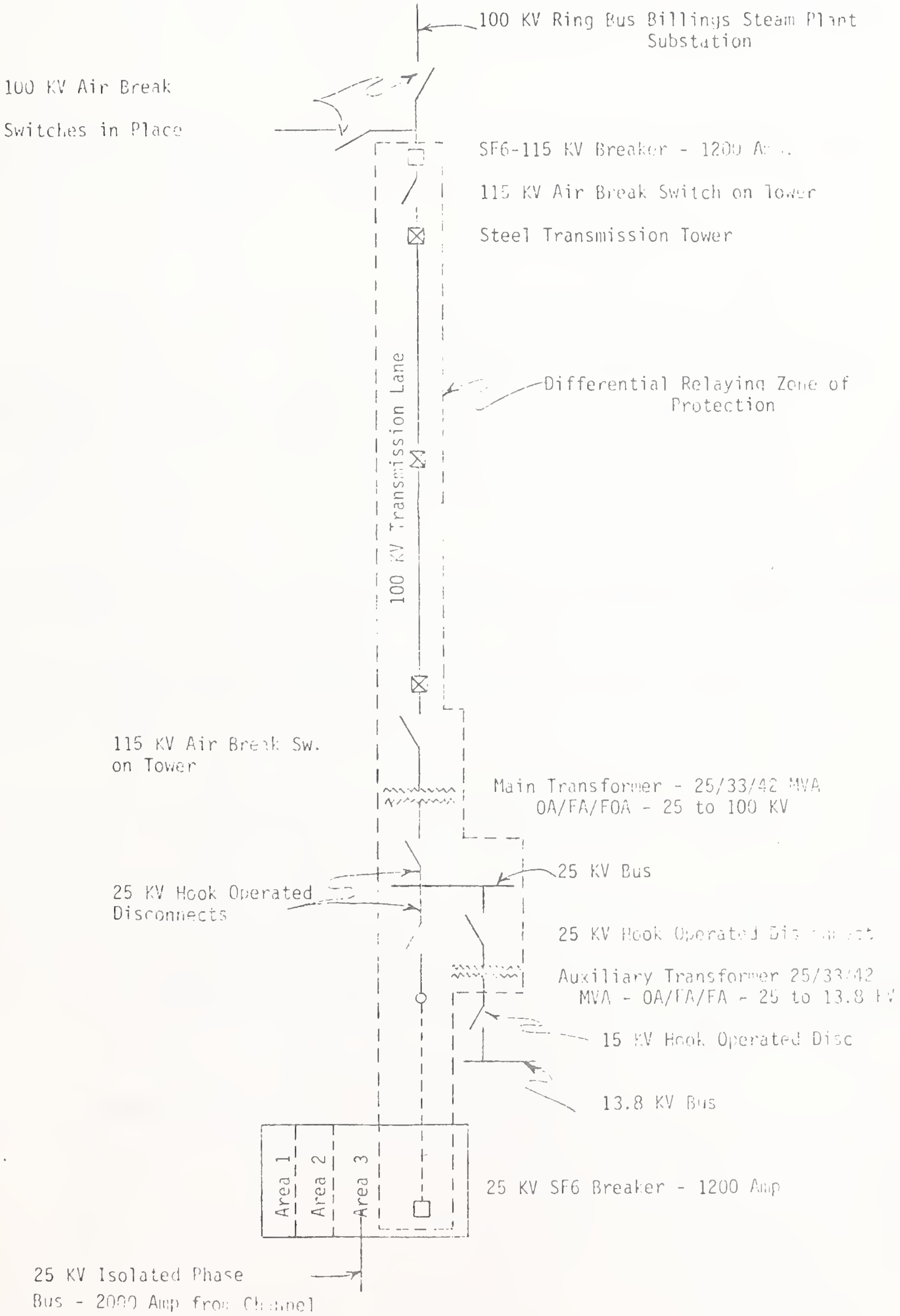

100 KV Ring Bus Billings Steam Plant Substation
100 KV Air Break Switches in Place
SF6-115 KV Breaker - 1200 Amp
115 KV Air Break Switch on Tower
Steel Transmission Tower
100 KV Transmission Lane
Differential Relaying Zone of Protection
115 KV Air Break Sw. on Tower
Main Transformer - 25/33/42 MVA OA/FA/FOA - 25 to 100 KV
25 KV Bus
25 KV Hook Operated Disconnects
25 KV Hook Operated Disconnect
Auxiliary Transformer 25/33/42 MVA - OA/FA/FA - 25 to 13.8 KV
15 KV Hook Operated Disc
13.8 KV Bus
Area 1
Area 2
Area 3
25 KV SF6 Breaker - 1200 Amp
25 KV Isolated Phase Bus - 2000 Amp from Channel

Figure 2-21 -- Substation and Transmission

From this breaker the output will be carried on three, size 1000 MCM, shielded 25 KV copper cables underground in six-inch PVC ducts encased in concrete. A copper neutral conductor (size 4/0) associated with this circuit will be solidly tied to the station ground mat and carried outside the six-inch duct and tied to the body of the pothead where the cables terminate.

Suitable valve type lighting arrestors will be installed adjacent to the pothead and will use the ground at the pothead.

The cables will rise up in six-inch galvanized rigid conduit at the substation, located about 75 ft northwest of the northwest corner of the Corette steam plant. The approximate route of the cables and duct is indicated on the site plan drawing number E02-DNRC-003.

The steel substation will provide a 25 KV aluminum bus rated at 1200 amperes and a 13.8 KV bus rated at 1200 amperes. The 25 KV bus will be fed by the underground cables through the 1200 ampere hook operated disconnects.

The main transformer rated 25/33/42 MVA-OA/FA/FOA -- 25 KV to 100 KV will be fed through 25 KV hook operated disconnects from the bus. This transformer will have four 2-1/2 percent taps so that it can be fed at 22.5, 23.1, 23.8, 24.4 or 25 KV. This transformer output at 100 KV will use size 636 MCM ACSR leads to rise to a 115 KV air break switch at the top of a standard steel transmission line tower adjacent to the substation.

An auxiliary transformer rated 25/33/42 MVA-OA-FA/FA -- 25 KV to 13.8 KV with taps similar to those in the main transformer will be installed with suitable hook operated disconnects on both the 25 KV and the 13.8 KV side.

The principal motor loads to be supplied from the 13.8 KV bus are the air separation unit and the oxidizer unit totaling just under 25,000 H.P.

The other motor loads are to be determined and will probably all be supplied by 480 volt three phase service which will require a transformer from 13,800 to 480 volts.

As indicated on the one-line diagram, the transmission line using size 636 MCM ACSR conductor may require three steel towers and will be approximately 600 ft in length to reach the northwest corner of the 100 KV ring bus at the Billings Steam Plant Substation. Care will be exercised to assure that proper clearance from all structures, ground, rails, and other conductors is adequate. The tower adjacent to the 100 KV ring bus will support a 115 KV air break switch and this will feed a type SF6 115KV circuit breaker to be connected to the 100 KV ring bus. This SF6 circuit breaker will be equipped with proper bushing type current transformers for differential relaying. There will be corresponding current transformers in the 25 KV SF6 breaker in the inverter building and on the 13.8 KV side of the auxiliary transformer. The secondary leads from these three locations will be arranged for differential relaying to open the 25 KV-SF6 breaker in the inverter building and the 115 KV-SF6 breaker near the ring bus. Any fault in the underground cable system, the 25 KV bus, the main transformer, the auxiliary transformer or the transmission system will cause these two breakers to open at high speed, giving adequate protection to the total system.

With the air breaks in the 100 KV ring bus and with the disconnect equipment planned, each piece of equipment and the transmission system can be individually isolated for any required maintenance work or inspection.

2.3 Utility Interfaces

The interfaces with the Corette plant are primarily in the steam, feedwater, water systems, coal, and control areas. Additional interfaces that involve the Bird plant as well as the Corette are the natural gas, fire protection, and the central control room. The major electrical interface is in the Billings Steam Plant Substation.

2.3.1 Steam

The design requirements for the steam interface between the ATS and the Corette plant should ensure that operational and functional impacts will be minimized. The high pressure systems should integrate readily with the existing systems and be easily controllable to respond to operational requirements. The Corette boilers minimal operational level should remain at an efficient and responsive level while allowing the steam electric turbine generator to operate at its nominal 163 MW_e level. Steam pipelines should be as short as practical to minimize heat and pressure losses and continue to allow adequate short time control responses.

Some lower pressure steam requirements, if available from the existing system, will be necessary to provide a heat source for ATS building heating loads in the heating/ventilating units. All of the new steam systems will require a method to capture condensate and return it to the Corette condensate system.

There will be three interface connections to the High Pressure Superheat Steam and Reheat Steam Systems to accommodate the additional steam as supplied from the HRSR boiler. The superheat steam flow will be controlled by the feedwater flow control valves, as shown on schematic D02-DNRC-001. The Corette boiler will be operated at approximately 57% of firing rate and the HRSR would then supply the additional 33% of steam flow to operate the turbine-generator at its nominal rating of 163 MW_e. The boiler recovery factor and efficiency curves of the Corette unit indicate that it be operated in the 60 to 70% range to minimize operational problems and still retain cost effective power generation. MPC may, at their discretion, operate at a turbine-generator output higher than the nominal 163 MW_e. An internal design evaluation of required steam flow, turbine stresses and other plant operating and capacity requirements would have to be made to ensure that the turbine generator is capable of the higher output. The Corette boiler would be capable of providing the additional steam requirements under those operating conditions.

The interface connection on the high pressure superheated steam will be into the existing 14 in. diameter steam line as it is routed to the turbine. The connection will be in the main ground floor pipe alley at an elevation of approximately 15 1/2 ft above ground floor.

The cold reheat steam interface will be at a similar location approximately 12 ft above ground level along the main ground floor pipe alley. That connection into the 24 in. diameter cold reheat steam line will be as close as possible to the turbine to provide adequate control sequencing and response time in the system.

The hot reheat steam interface will also be in the main ground floor pipe alley approximately 12 ft above the floor. This connection will be into the existing 22 in. diameter hot reheat steam line.

To provide heating in the new facility the existing 175 psig steam system will be interfaced and extended to the heating/ventilating units in the areas requiring heat, if design calculations confirm steam availability. This expansion of an existing system ensures adequate freeze protection of the new buildings during periods of non-MHD operation.

Figure 2-22 outlines the major steam interfaces and Table 2-9 summarizes the steam and feedwater flows at boiler stop valves.

Additional interfaces will be required to adequately collect any low pressure or high pressure condensate drains. Those drains will be connected to the appropriate condensate system now in use at the Corette plant which returns to the turbine condenser.

2.3.2 Feedwater

The feedwater requirement for the HRSR should be of similar quality as is presently fed to the Corette boiler. To overcome additional frictional losses in the piping system, provision should be made to increase the pressure of that feedwater. The interface should ensure that operational and functional impacts are minimized and that ease of operation with adequate responsiveness remains.

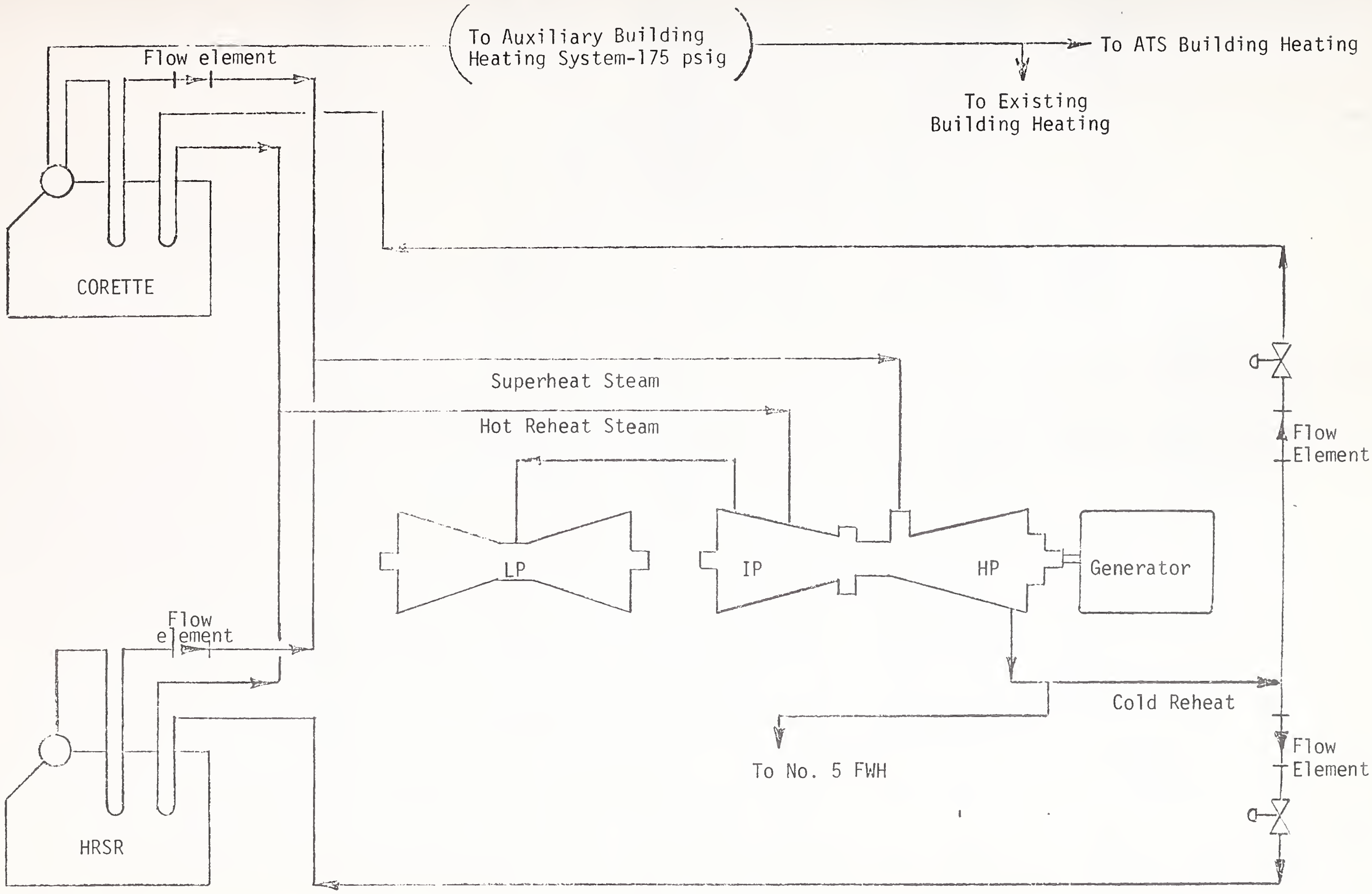


Figure 2-22 -- Steam

TABLE 2-9

BOILER STOP VALVE

STEAM AND FEEDWATER

ITEM	SOURCE	TO	LBM/HR
Superheat Steam	Corette	Turbine	7.462×10^5
Superheat Steam	HRSR	Turbine	3.675×10^5
Total Superheat System		Turbine	1.1137×10^6
Cold/Hot Reheat Steam	Turbine	Corette	6.363×10^5
Cold/Hot Reheat Steam	Turbine	HRSR	3.134×10^5
Total Cold/Hot Reheat System		Corette/HRSR	9.497×10^5
Feedwater	FW Heater	Corette	7.500×10^5
Feedwater	FW Heater	HRSR	3.134×10^5
Total Feedwater		Corette/HRSR	1.1192×10^6
Blowdown	Corette/HRSR		0.055×10^5

The HRSR boiler feedwater requirement will be supplied by the existing Corette feedwater system, as shown in Figure 2-23. The assumption is made that at the reduced rate of firing in the Corette boiler, adequate feedwater is available to both boilers as the combined steam flow to the turbine-generator remains at its nominal operating level of 163 MW_e. The existing evaporative makeup system will be assessed for adequacy to provide adequate makeup water supplies to offset boiler blowdown, sampling, or other losses. If MPC elects to operate the turbine-generator at an output greater than 163 MW_e they would conduct an internal design evaluation of the required feedwater and condensate flows.

An electric driven booster feedwater pump in the feedwater line to the HRSR will be required to overcome additional pipeline frictional resistance. That resistance is due to increased length of pipe runs to the HRSR and the cooling loops through the combustor, MHD channel, and diffuser. Initial filling of the HRSR will require plant coordination during periods of normal Corette boiler operation.

The feedwater interface connection will be between the condenser and number five feedwater heater. The location of the connection will be in the main ground floor pipe alley in the vicinity of the existing feedwater pumps and approximately 12 ft above ground level. Figure 2-23 shows the major feedwater flows for the Corette ATS plants.

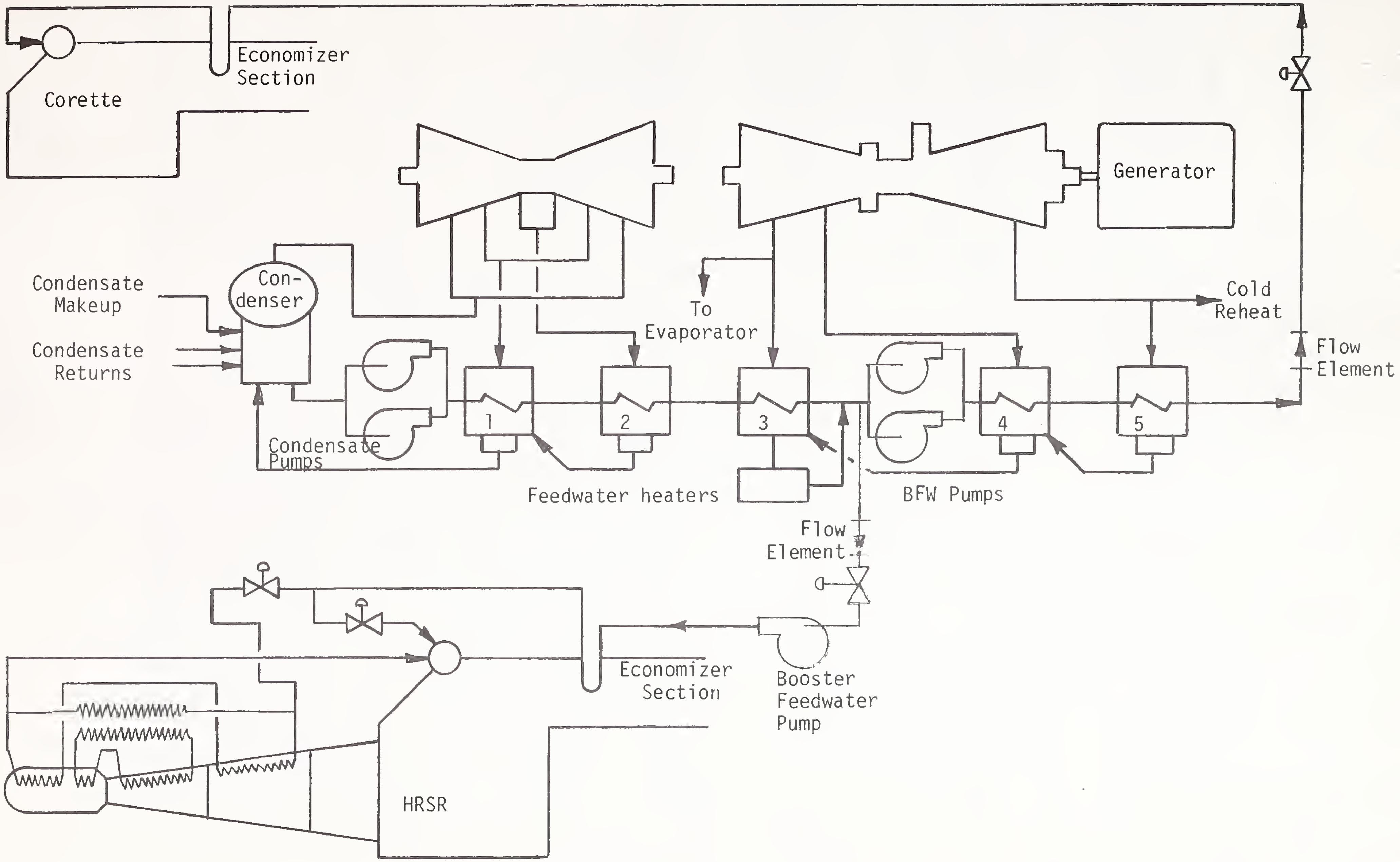


Figure 2-23 -- Feedwater

2.3.3 Water Systems

Interface design requirements for the closed-loop cooling water systems will require initial filling and makeup of high quality water to minimize corrosion, scaling, and makeup requirements in the various sytems. A source of cooling water from the Yellowstone River is required to dissipate low-grade heat from mechanical equipment as well as provide minimum usable requirements in the ATS. Consumable water usage and clean filtered water requirements should be supplied from the city water supply. Additional fire protection requirements should be satisfied from the existing plant-wide fire protection system. Sketches provided in previous sections have indicated interface requirements on these systems. A separate table showing total water requirements is included in this section.

The MHD channel cooling water system, inverter cooling water system, and the bearing cooling water system will have an interface with the Corette condensate system. Initial filling of the system will be with that high quality water. During normal ATS facility operation the water makeup will be minimal and should be satisfied from the Corette system. Coordination between the two plants will be necessary during the initial filling to minimize any impacts with the Corette boiler operation.

A separate service water pump will be installed to provide primary cooling water requirements to the lube oil coolers and makeup water requirements to the CFC slag handling system, HRSR bottom ash system, blow-off quench tank, and washdown hoses. The pump will use an existing intake structure located

on the Yellowstone River. Heat load requirements should be balanced between the ATS and Corette plants when both are operating and providing steam to the turbine-generator at the nominal 163 MW_e level. An internal design evaluation of cooling water requirements would be made if turbine-generator output beyond 163 MW_e was desired.

A potable water break tank similar to the existing one would be installed to provide a constant head for pump gland seal water and consumable potable water usage. The interface and supply will be from the existing plant city water system.

The existing fire system will be interfaced with and be extended around the new building perimeter if design calculations determine the adequacy of the present systems. Wet risers for the ATS will then be supplied from the perimeter fire main system.

Table 2-10 summarizes the water usage requirements for the ATS.

2.3.4 Fuels

Two fuel interfaces are required with the existing Corette and Bird plants, the major one being the primary fuel, coal. The second requirement will be for a natural gas supply from the present system connected to both the Corette and Bird plants.

TABLE 2-10

WATER USAGE

	GPM	T°F	Blowdown	Makeup
Feedwater	1437	----	29	29
MHD Channel Cooling	1100	100°	--	--
Inverter Cooling	200	20°	1	5
Bearing Cooling	2100	73°	--	25
Service Water Intermittent to 3000 GPM	1600	51°	--	--
Potable Water	40	----	--	40
Fire Protection	As Required			

2.3.4.1 Coal

The interface design requirement for coal, the major firing fuel, is to provide an adequate supply of coal to the ATS while not interrupting the present supply of coal to the Corette plant. Interfacing with the existing coal supply system would simplify the coal system design and would greatly reduce the construction costs of that system.

The interface would be at the existing coal reclaim tunnel or optionally along the existing no. five coal conveyor. A new conveyor will then transfer a side stream of coal to the ATS coal bunkers for further processing in the coal preparation system. The existing reclaim system was designed to handle 200 tons per hour, a sufficient flow for two units the size of Corette. As the Corette's maximum operating design is 100 tons per hour the requirement for an additional 50.7 tons per hour of coal to the ATS can be met. Refer to the sketches and tables in the previous sections for details of the coal preparation system.

2.3.4.2 Natural Gas

There is a requirement for a pilot fuel in the coal fired coal predryer, pulverizer air heater, and the MHD power train CFC for startup and stabilization during firing. In addition, startup, off-load, and abnormal operation of the ATS will require an alternate fuel to stabilize the HRSR operation and provide a more compatible steam interface with the Corette plant.

An interface with the existing regulated natural gas header will supply fuel to the pilot ignitors on the coal predryer, pulverizer air heater, and the CFC. The natural gas supply will be adequately sized to provide the potential firing of the HRSR boiler during periods of non-MHD operations. This is not a continuous operating mode but would allow the combined plant an opportunity to compensate for off-load or abnormal operating conditions.

The existing regulated natural gas system has an approximate capacity of 900 MCFH for the Corette unit warm up guns and rated firing of the Bird unit. The sketches in previous sections detail the gas system. The use of pilot ignitor gas would only be during initial firing of the coal predryer, pulverizer air heater, or CFC. Approximately 200 MCFH of gas would be used during alternate firing of the HRSR with 30% rated warm up guns. The total available supply of gas would restrict the HRSR firing and eliminate that firing when the Bird unit was needed on line.

2.3.5 Instrumentation and Control

It is planned that the existing utility plant will be treated as a local system and be controlled by the supervisory computer through commands to the existing control system. Operating points, such as modes (boiler following, turbine following) and operating power levels will be set by the supervisory computer. Steam system operating parameters and alarm levels will be returned to the supervisory computer for status monitoring and for integrated plant control in the event of an emergency. There will be only a few high bandwidth interconnections that will be routed from the existing Corette

control room to the individual ATS subsystem control microcomputers. The utility, in this case Montana Power Company, will have operational control of the supervisory computer.

2.3.6 Electrical

The plan is to locate the steel substation so that the transmission tower nearest the substation will just clear the coal conveyor, being directly south of it. Drawing E02-DNRC-003 provides a layout of the site plan outlining these areas. There is some cable power wiring and a telephone cable on the steel towers that support the coal conveyor to the Corette plant. These cables can all be raised or re-routed on the support towers to remain in the clear of the proposed substation.

The 100 KV transmission line will be about 600 ft long and will extend to a vertical corner pole directly west of the construction warehouse, with an overload guying arrangement over the railroad tracks and toward the day fuel oil tank. From the vertical corner pole, the line will run in a direct line to dead-end on the existing steel tower at the northwest corner of the 100 KV ring bus.

The differential relay arrangement will protect the Montana Power Company 100 KV ring bus from any faults between the inverter and the bus with high speed switching of the SF6 breakers.

2.3.7 Buildings and Structures

One of the previously stated design requirements was for close proximity of the HRSR to the existing Corette turbine-generator to reduce steam and feedwater pipeline lengths thus allowing continuing operation of the turbine-generator at its nominal rated output. This necessitates that the ATS should be located adjacent to the Corette plant taking into consideration existing road and access requirements for the Corette. This close location would also reduce the lengths of interface connections required for the closed cooling water loops, service water intake structure, potable water, fire protection system, and primary fuel. The existing coal reclaim system should be used to reduce duplication of systems. Utilizing the available land and area as well as providing access to the Corette unit and the existing operating offices is a requirement for the design. The ATS should be located to effectively use the existing rail and road facilities for access during construction, startup, and operational phases of the project. Any rail or road movement must be coordinated with the Corette plant to not interrupt coal unloading operations. Control of the Corette must be closely coordinated with any operational requirements of the ATS, therefore, making the physical proximity of the controls for both plants a necessity. The minimization of costs by locating buildings and structures in a fairly unrestricted area adjacent to the existing plant and interfacing with existing operational equipment is a primary design requirement objective.

The ATS building, structural, and area layout is shown on drawings E02-DNRC-003 and C02-DNRC-004. This layout shows an integrated island within the available area adjacent to the Corette plant. Locations of specific interfaces, such as the service water pump, control room, pipe bridge, seed railcar unloading and coal conveyor takeoff, are determined by existing plant and equipment configurations.

2.4 Site

This section will address the land and area requirements of the MHD power train and the support systems of the ATS. The location available at the MPC thermal plant facility at Billings, Montana is limited in area and in configuration. The site available is bordered on the west by the main access road, railroad service, fuel oil storage tank, and coal storage; on the south by the Corette and Bird thermal power plants; and on the east by the Bird plant main transformer, and the intake and discharge canals for the Corette plant. The Yellowstone River also confines the eastern as well as the northern boundary of the available area for the ATS. Preliminary sizing was done in preceding sections and those building descriptions were used in developing the general plot arrangement as shown on drawings E02-DNRC-003 and C02-DNRC-004.

2.4.1 MHD Systems

The basic MHD layout lies immediately north of the Corette plant and was arranged to minimize the lengths of the superheat, cold reheat, and hot reheat steam lines to the turbine-generator. Access to the main service doorway on the north side of the Corette was also required as well as access to the operational offices of the present facility. The cryogenic building was located as close as possible to the SCM to eliminate lengthy liquid helium lines. The inverter building was also located close to the MHD channel to reduce the length of the DC power transmission lines. The coal bunkers and coal preparation facility were located in an area to provide ready access to the existing coal reclaim system and to isolate any potential

fire and explosive hazard from the existing Corette plant. A direct route for the main 100 KV transmission line was also considered in the layout of the buildings and structures. Some interference with the existing No. 5 coal conveyor was a concern and layouts were made to avoid that problem. The remainder of the facility was arranged to provide access for equipment maintenance, ease of bulk consummable commodity delivery, and convenience for removal of bulk waste material within the physical confines of the area.

Initial construction, startup, and operational phases will require considerable interface with contractors, suppliers, manufacturers, and technical personnel. Separate construction management offices, construction personnel parking, and construction staging areas will have to be coordinated during the various project phases. The administration building was sized to accomodate nominal staffing requirements for those phases of the project and also provide the future capability to convert those offices and facilities to operational offices. As such the administration building required adequate roadways and parking areas in close proximity.

2.4.2 Interface Systems

The interface system discussed in this section will be those areas of direct interface with the existing Corette plant that impact siting considerations.

2.4.2.1 Steam and Feedwater

Superheated steam, cold and hot reheat steam, and feedwater will be the primary interface between the ATS and the Corette Plant. Those interface

connections will be in the main ground floor pipe alley of the existing plant and a main pipe bridge between the two facilities. Other interfaces, such as 175 psig steam, evaporator water and potable water, will be routed over this pipe bridge. A pipe alley will be incorporated within the new building structures and will include other piping runs as required. Due to the closeness of the two facilities the interconnecting pipe bridge will not require extensive additional area.

2.4.2.2 Water Systems

Any site considerations for the various water systems is determined by the system itself and its interface with the existing plant. The service water system will utilize an existing intake structure with the pump mounted on the adjacent concrete pad. Routing of the buried pipeline will be deep enough to avoid freeze protection and routed through an open site area; although it will traverse the existing underground pipelines from the Corette intake and discharge structures.

A cooling tower for the inverter cooling water system will be located to prevent significant deterioration of close structures. The supply and return pipelines will be located within the confines of the ATS and should not interfere with any of the existing plant related equipment.

The existing underground perimeter fire protection system on the north side of the Corette Plant will lie underneath the ATS buildings. That fireline would be relocated to provide perimeter protection to the new buildings as well as continuing the fire protection for the existing plant.

2.4.2.3 Fuels

The interface for the natural gas will be at the existing regulating station located south of the Corette main transformer. Routing of that underground pipeline will parallel the existing six-inch pipeline to the Corette boiler which runs outside of the building along its south and west side. The new gas line will continue to points of use in the ATS with no interface anticipated.

The interface with No. 5 coal conveyor will be at the coal reclaim system inside the coal reclaim tunnel or optionally could be located along the length of No. 5 coal conveyor. This decision will be made during the design phase of the project when further analysis of costs, operational requirements, accessibility, interferences, and additional interfaces can be made. The new coal conveyor will be routed overhead above the railroad and main access road to alleviate clearance and interference problems. It will discharge on top of the new coal bunkers for distribution to those two bunkers.

2.4.2.4 Electrical

The inverter will have a major interface connection to the existing switchyard with the appropriate towers and 100 KV power lines. The location of the main transformer and tower support is critical to miss any overhead interference with No. 5 coal conveyor and to establish a direct routing to the 100 KV bus in the switchyard.

2.4.2.5 Bottom Ash

The existing ten in. cast bottom ash pipeline discharge from the Corette boiler runs in a northerly direction above ground to the bottom ash disposal pond. That pipeline will have to be relocated to skirt around the new building structures of the ATS.

2.4.3 Liquid Waste Storage and Disposal

Waste water from the ATS will consist of water from the CFC slag handling system, bottom ash sluicing system, blow-off quench tank, demineralizer regeneration, and floor drains. All of these flows will be directed to the water treatment plant where they will be processed for recycling or eventual discharge to the Yellowstone River via the existing bottom ash ponds. The bottom ash ponds should be evaluated for loading consideration and environmental consequences during the preliminary design. Due to the intermittent nature of the discharges there will be surge capacity storage at the water treatment plant to stabilize water treatment processing flows and provide for unusual conditions of the ATS. All floor drains will be routed through an oil separator before surge tank storage. The routing of the discharge pipeline to the Yellowstone River will traverse an open area and should pose no siting problems. Figure 2-24 identifies the major sources of liquid waste and water treatment process.

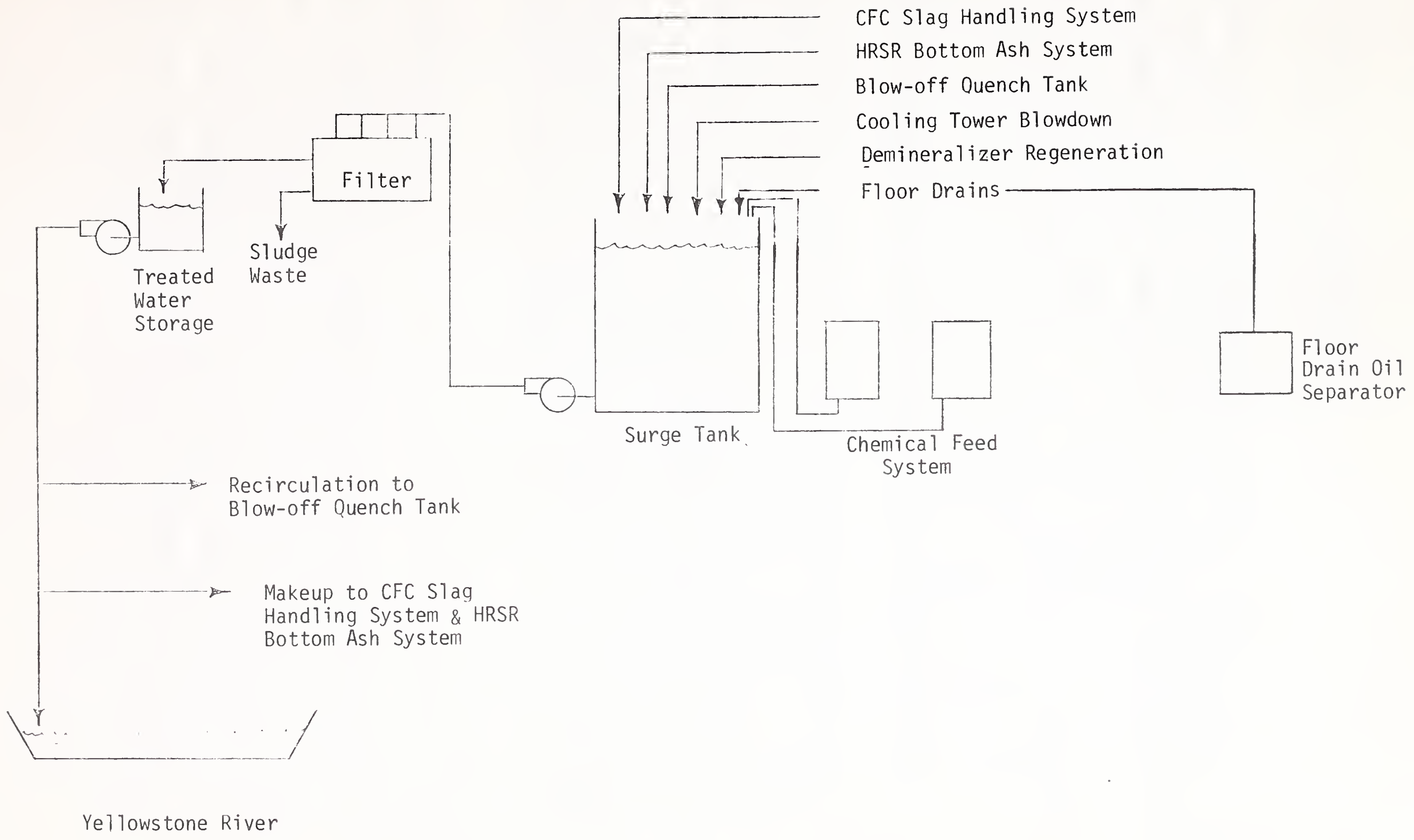


Figure 2-24 -- Liquid Waste

2.4.4 Solid Waste Storage and Disposal

The dewatered slag from the CFC slag handling system will constitute the largest volume of solid waste material requiring disposal. This material will be transferred from the dewatering bins to intermediate storage where it can then be sold for asphaltic material or optionally loaded onto trucks for off-site disposal at a land-fill area. Some filter sludge will be generated by the filtration process in the water treatment plant and will have to be disposed off-site. The bottom ash sluicing system will also use dewatering bins with an intermediate storage for disposal of the dewatered bottom ash.

Each fly ash silo will have material with varying percentages of potassium related compounds and fly ash. The silos and intermediate bottom ash storage will have provisions for truck loading and the material with high potassium content will be transported off-site to a permanent storage facility for future processing. The remainder of the material will be disposed at a land-fill area or sold as a cement filler. Figure 2-25 identifies the source and disposal of the ATS solid wastes.

2.4.5 Transportation

The site currently has rail transportation service from Burlington Northern Railroad and has adequate trackage and spurs for the ATS and the present plant requirements. The location of the main trackage is parallel to the ATS and will afford the opportunity of constructing a construction spur to accomodate off-loading major ATS construction components close to the new installation. Railcar delivery of consumable material would be advantageous

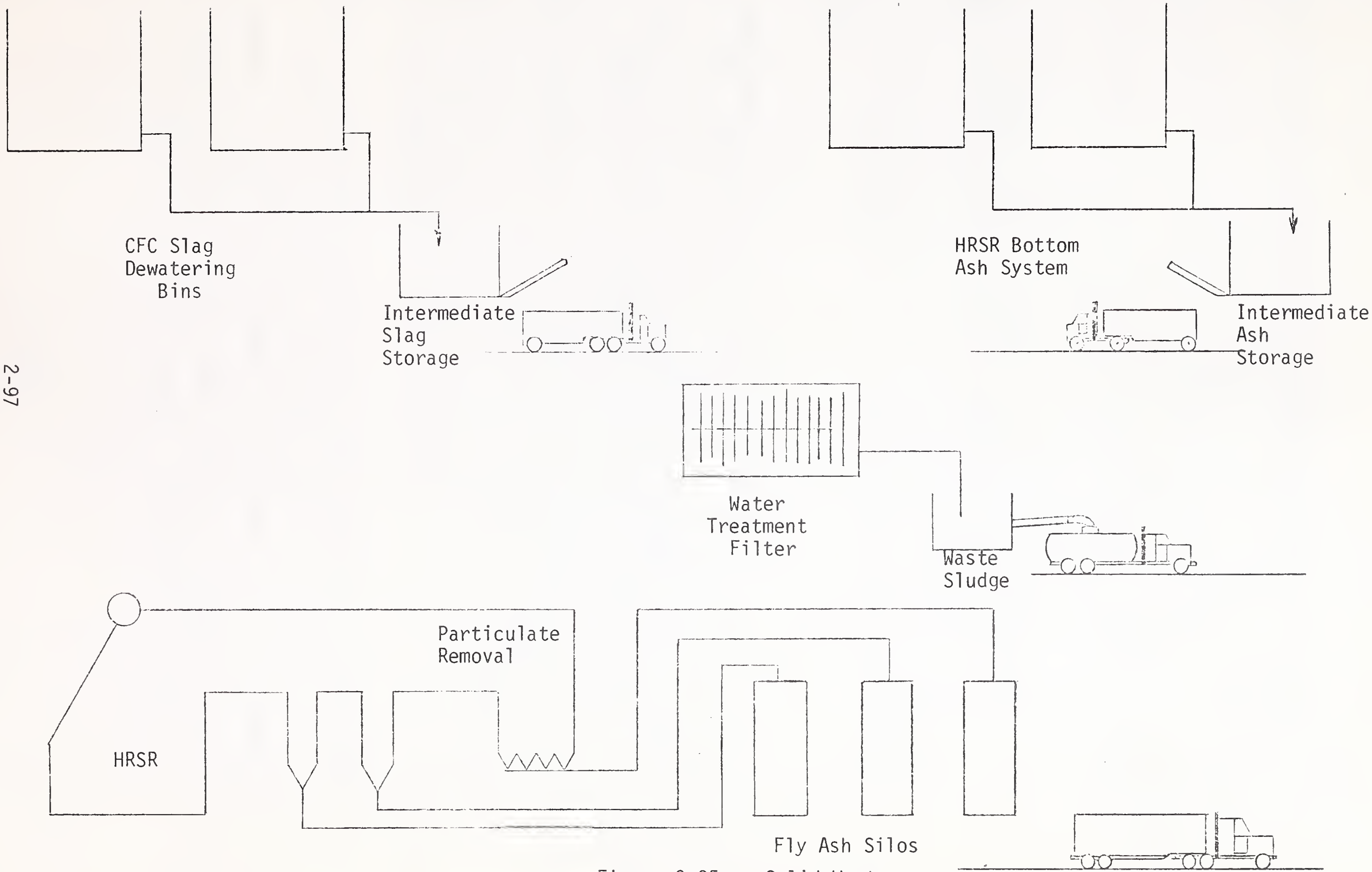


Figure 2-25 -- Solid Waste

and readily designed into the facility. The primary material delivered by rail would be seed and should not interfer with coal delivery. Consumption is minimal with deliveries anticipated every seven to ten days.

The City of Billings is on the national interstate highway system and the MPC site is adjacent to Interstate 90 with access within one-half mile from the plant site. The site roads are adequate for delivery of material and equipment of the sizes anticipated for construction and operation of the ATS. Provision for road access to the north side of the Corette plant will be required to allow continuation of the existing operational and maintenance activities.

2.4.6 Land, Building, Structures, and Area Requirements

The layout of the buildings and structures on the available land, as shown on drawings E02-DNRC-003 and C02-DNRC-004, was predicated in regard to the following: 1) maintaining close proximity to the turbine-generator; 2) utilizing existing main roadways and railroad trackage; 3) adjacent to coal transfer points; 4) closeness of existing plant services; and 5) minimization of the cost of construction and plant modifications.

In general, all buildings will be of steel frame construction with insulated metal siding and built-up roofing. Buildings adjacent to each other will share common wall construction. Mandoors, large access doors, and stairwells will be integrated within the entire complex as well as a centrally located elevator for personnel and maintenance access. Heating/ventilating and air conditioning systems will be integrally designed as a part of the structures

paying particular attention to comfort zoning and fire protection requirements.

2.4.6.1 MHD

The MHD building will be located at the center of the MHD complex with access to roadways for ease of entrance or egress. It will house the coal fired combustor (CFC), MHD channel, diffuser, superconducting magnet (SCM), channel and magnet control instrumentation, slag quench tank, slag dewatering bins, and the magnet D.C. power supply. The walls adjacent to the operating field of the SCM will be shielded to prevent stray magnetic fields from affecting equipment or personnel. Shielded internal walls in the building will be required to take advantage of the entire area for auxiliary equipment. The 100 ft by 150 ft building will be 80 ft high. A 150 ton bridge crane will span the 100 ft width of the building and be used to facilitate the initial erection of the equipment and for continuing maintenance operations. The magnet is mounted on a foundation and the MHD channel is inserted and withdrawn from the large exit end of the SCM for maintenance. To facilitate slag rejection from the coal fired combustor and to eliminate construction, maintenance, and housekeeping problems a ground level handling system, including slag dewatering bins, is recommended.

2.4.6.2 Control Room

The central supervisory control for the ATS operation will be located in the existing Corette control rooms. The data acquisition system (DAS) will be included in this area as an integrated part of the control functions.

2.4.6.3 Heat Recovery/Seed Recovery

The HRSR will be housed in a 100 ft by 100 ft building envelope with a height of 80 ft The radiant and the convective portions of the HRSR as well as the economizers and air heaters will be housed in this building. The lower floor levels will include such major equipment as the circulating boiler pump, booster feedwater pump, bottom ash sluicing system, seed and ash collection system, and various air blowers. The ash sluicing system will use dewatering bins that can be located inside the HRSR building. The recovered seed and ash material will be transported to outside storage silos where it will be removed from off-site storage.

2.4.6.4 Inverter

The inverter building will house the thyristors, inverter, switch gear, and instrument and control functions. The 125 ft by 70 ft structure will be 24 ft in height. The building will be located as close to the MHD building as possible to keep interconnecting power transmission line losses to a minimum. The main transformer, auxiliary transformer, and necessary towers will be located in a a substation area of 70 ft by 50 ft that would be close to the building with clear access toward the existing switchyard. The 25 ft by 12 ft cooling tower for the thyristor heat load will be located at the edge of the complex to take advantage of a more open area for evaporative cooling.

2.4.6.5 Coal Preparation

The coal preparation area will include two coal bunkers (33 ft x 21 ft each) at the north side of the ATS facility. A new take-off point at the coal reclaim tunnel or along No. 5 coal conveyor will provide coal feed to these bunkers. The bunkers will discharge to the coal crusher and predryer which will be located immediately below the bunkers in an open steel frame coal drying building with dimensions of 33 ft by 100 ft. The upper height of the coal bunkers will be 80 ft and the portion of the coal drying building not underneath the bunkers will have a roof elevation of 24 ft The bag house for the coal predrying will be located north of and adjacent to the building. The 30 ft high bag house will cover a 40 ft x 15 ft area.

The adjacent coal preparation building will house the remaining components such as coal pulverizers, screens, storage vessels, injection vessels, and conveyors. The 40 ft by 60 ft structure will be 80 ft in height. This building will have blowout panels due to the combustible nature of the finely pulverized and dried coal. The cyclone will be located on the roof of this building and the bag house (for the coal preparation system) will be to the north of the ATS building complex. The 40 ft high bag house will cover a 50 ft by 20 ft area.

2.4.6.6 Seed

The seed handling building will house the crusher, screen, and seed injector lock hopper system. The building will be 20 ft by 30 ft with an elevation

of 24 ft. Primary storage will be external to the building in two storage silos of 500 ton capacity each.

2.4.6.7 Cryogenic

The cryogenic systems building for the air separation plant and the SCM cooling system will house the main air separation plant compressor, blend air compressor, vacuum pumps, auxiliary equipment, instruments, controls, and the liquid helium storage dewar. The cold boxes and columns for the air separation units, liquid oxygen storage, and liquid nitrogen storage will all be located outside and adjacent to the building. The building size will be 75 ft by 40 ft. A 20 ton house crane will be included in the building for erection and service requirements of the installed heavy equipment. The portion (40 ft x 40 ft) of the building adjacent to the SCM will be 50 ft in height so that the liquid helium dewar can be placed at a high enough elevation to produce as least one atmosphere of gravity head against the SCM and eliminate pumping costs and reduce the length of the transfer piping to minimize heat losses. The remainder of the structure will be 24 ft in height.

2.4.6.8 Water Treatment

A small building for water treatment of final discharge wastes from slag handling, bottom ash sluicing, boiler blowdown, demineralizer regeneration, and plant washdown is envisioned to provide acceptable quality of water for recycling or eventual discharge into the Yellowstone River. The building would house filters for suspended solids removal and treatment chemicals to

restore the proper chemical balance. The 40 ft by 33 ft building will be 24 ft in height.

2.4.6.9 Auxiliary Equipment

An auxiliary equipment building will be needed to house the service and instrument air compressor, lube oil coolers, secondary cooling water systems, and other related equipment for operation of the facility. The 50 ft by 60 ft building will be an integral part of the other support related structures and be 24 ft in height.

2.4.6.10 Particulate Control Device

The 50 ft by 100 ft structure will be elevated to accommodate seed and fly ash removal at the ground level. The total height will be 50 ft An adjacent silo will accept fly ash material on an interim basis for off-site removal.

2.4.6.11 Stack

The reinforced concrete stack will be the tallest structure of the complex at an estimated height of 250 ft The minimum height required will be 200 ft to clear adjacent building structures and the final height will be determined by computer dispersion modeling. An inner steel liner will carry the cleaned HRSR exhaust gas. Sampling stations and platforms will be provided as well as exterior hazard warning lights in accordance with FAA requirements.

2.4.6.12 Maintenance

A maintenance building to handle specialty maintenance procedures on MHD system components will be located adjacent to the MHD building. An instrument shop and an area for other routine maintenance will also be in this building. A 20-ton house crane will be included in this 50 ft by 80 ft by 24 ft high building.

2.4.6.13 Warehouse

A warehouse storage area is anticipated for additional storage or warehousing of specific MHD component materials as well as maintenance items for the other support equipment. Some operational materials may also be stored in this 40 ft by 40 ft building which is 24 ft in height.

2.4.6.14 Administration

An administrative building would house the normal office functions in addition to plant supervisory personnel, engineering staff, visitors, lunch room, men's and women's locker rooms, and toilet facilities. A septic tank and leach field will be used to dispose of the sanitary wastes as the plant site does not have access to the city's sewer system. The 40 ft by 80 ft structure would be 24 ft in height and have adjacent parking areas.

A designated operations area of 20 ft by 40 ft in the administrative building will be used as a central location in the facility to dispatch operators to the various plant support areas. This room will also contain as many local

area control microcomputers as is practical given distance and proximity requirements. A second floor above the operations room would allow additional room for instrument or control functions.

2.5 Modifications

This section addresses those modifications to the Corette plant that are necessary to allow retrofit of the ATS to the Corette. The primary ones are those at the main interfaces of steam, feedwater, control instrumentation and electrical power. These interfaces as well as several of a secondary nature will require careful design and integration into existing systems.

2.5.1 Steam and Feedwater

There are four major interface modifications to the existing Corette plant steam and feedwater systems. All of these modifications are anticipated to be in the main ground floor pipe alley. The first would be in the 14 in. diameter high pressure superheated steam supply to the turbine. The installation of a flow sensing device and the actual interface connection from the HRSR high pressure superheated steam are required.

The second area of modification will be in the 24 in. diameter cold reheat steam after it leaves the turbine. This will require a sensing device, flow control device and routing a cold reheat steamline to the HRSR. The third modification will be to the 22 in. diameter hot reheat line as it is routed to the intermediate stages of the turbine. This will require only the interface connection where hot reheat steam returns from the HRSR on its way to the turbine.

The final major modification will be to the feedwater heating system. The 10 in. feedwater line will be tapped for HRSR feedwater at a position between the condenser and number five feedwater heater. A flow sensing device, flow control device, and the interface supplying feedwater to the HRSR are anticipated in this modification. The resulting unbalance between feedwater heater heat required and steam supplied from the generator will require control valves in at least some of the steam lines leading to the feedwater heaters. These steam control valves will be controlled by the feedwater temperature at the outlet of their respective heaters.

There will be minor modifications to the Corette steam and condensate system which will be more appropriately detailed during subsequent design phases. These modifications will consist of the following: expansion of the 175 psig steamheating system, low pressure condensate and high pressure condensate return interfaces, and condensate makeup supplier for the ATS condensate storage tank.

2.5.2 Water Systems

The modifications to supply condensate to the MHD channel cooling water, inverter cooling water, bearing cooling water, chemical feed, and HRSR fill and wash pump systems have been identified in the previous section. Those modifications will be at a single interface connection located at an outlet on the existing condensate storage tank which will supply a new ATS condensate storage tank. A removable spool piece that could be connected to the city water supply is also considered necessary for this modification to allow an alternate supply of clean water to those systems during initial

checkout and startup. A modification allowing use of the existing Corette intake structure for service water will be minimal as that intake pipe is not in use at present. A modification to the existing city water supply is planned for makeup to the potable water elevated break tank. That interface connection should consist primarily of extending the existing city water line.

A modification to the existing Corette plant fire protection system is required. This will be an extension of the perimeter system that is presently routed around the plant site.

2.5.3 Fuels

Coal and natural gas are available at the Corette plant. Modifications to both the coal and natural gas systems are necessary to permit usage of both sources. A major modification to the coal system will be required to provide an adequate supply of coal to the ATS. An interface at the existing coal reclaim tunnel or optionally along the no. 5 coal conveyor will require a major design modification to facilitate the diversion of sufficient coal quantities to support the operation of the ATS.

A modification to the regulated natural gas system will be required to provide pilot ignition and HRSR warm up gun fuel supplies. This interface will be a new gas supply pipeline connection immediately after the existing Heart Mountain Regulating Station.

2.5.4 Effluent

Any liquid wastes generated in the ATS will be directed to the water treatment plant where they will be reprocessed for recycling. If the flow balance does not allow all water to be recycled, a discharge to the Yellowstone River is anticipated. Other than physically routing the pipe for discharge, there should be no modifications to the existing system.

It is planned that the slag and bottom ash solid waste material will be sold for asphaltic material filler or transported to an off-site disposal area. There could be periods when some on-site storage would be necessary for a short time at the location of the present ash storage. No modifications would be required, but storage capacity would be limited due to land availability.

2.5.5 Control Instrumentation

Modifications to existing control methodology in the Corette plant will be required at two points. The first point will be in the existing control room where control lines will be added to and from the new supervisory computer. The computer will be installed in the existing control room to facilitate utility operator control.

The second point will be in the reheat steam and feedwater loops from the turbine. Flow diverting valves and control instrumentation are required at the locations where the ATS plant picks up reheat steam and feedwater. These valves are necessary in order to keep the reheat steam and feedwater flows to the two boilers at the same ratio as superheat steam is being supplied.

2.5.6 Electrical Systems

There are no planned modifications to the electrical system of the Corette plant. Currently there is no electrical capacity available for the MHD retrofit; thus, the anticipated electrical system will be independent of existing MPC service except for a connection to the 100 KV ring bus at the Plant Substation. This connection will not interfere with present MPC operations.

2.5.7 Site

Modifications to the site are minimal as the available area is generally open, level and been used previously for construction staging areas. A construction office building and oil storage building are presently on the site and will necessitate removal or relocation. Portions of existing drives, parking areas, or seeded lawn will require modifications to allow road building and construction facilities parking. Modifications also will be required to adapt the rail spur for bulk unloading of consumable materials.

The power supply and communication cables strung along the No. 5 coal conveyor support columns will have to be raised to allow adequate building clearance. These support columns will require additional study during the preliminary design phase as the present configuration would have some building interference with the columns.

Three pipelines have been identified for positive relocation requirements. These lines are the 36 in. yard drain with various catch basins, 10 in. Corette bottom ash discharge to the ponds, and the oil separation discharge line to the Corette discharge structure. These can be relocated outside of the ATS perimeter to prevent interference during construction. A routing for the new discharge line from the water treatment plant will traverse open land and should require no modifications to the existing line.

2.6 Operational

In this section the operational considerations as previously defined for the retrofit configuration will be discussed. This discussion is limited to unique or critical aspects of overall plant operation.

2.6.1 MHD Systems

The coal-fired combustor, MHD channel and diffuser will require thorough prestart-up operational checkouts. Operation of the other MHD systems, MHD support systems, and the Corette systems will be integrated into a startup procedure requiring approval from the Corette plant utility superintendent. Continuing MHD operation, as well as MHD shut down procedures, will be coordinated and approved by the Corette plant utility superintendent.

Prior to ATS startup, the cooldown of the superconducting magnet to 4.5° K must be accomplished, as well as the establishment of the initial vacuum in the helium system, and recirculation of helium to maintain temperature requirements during operations.

The HRSR boiler and associated system will have a startup procedure independent of actual MHD operation. Natural gas warm up guns would be inserted and fired to preheat the boiler and provide thermal circulation to avoid excessive high temperature thermal stresses when the MHD power train is started up. Any generation of low grade steam during this time or during initial firing of the MHD power train would be fed into a turbine bypass system to avoid the problem of two varying grades of steam being fed to the

Corette turbine-generator. The turbine bypass systems would be designed as a separate system with the capability of addressing the superheat and reheat steam requirements of the turbine-generator during the startup operation. Both the turbine-generator manufacturer and HRSR supplier would require consultation during the preliminary design phase. When the quantity and quality of the HRSR superheated steam approaches that of the Corette boiler, the supervisory control would slowly integrate that steam into the turbine system while compensating for the Corette boiler steam load and adjusting to turbine requirements.

On the approval of the Corette plant utility superintendent the AC output switch from the inverter will be closed when the MHD electrical power generated is compatible with criteria established. A failure of the MHD power train, through planned relaying, can open the AC output switch and isolate the inverter from any backfeed.

The Corette plant utility superintendent will have the ultimate control of both the Corette plant and ATS through the supervisory control system. The supervisory control not only interfaces between the two units but also is the master control for all of the ATS systems local area control microcomputers. The Data Acquisition System is a subsystem of the supervisory control system and as such is always operational during ATS facility operation.

2.6.2 Support Systems

The filling of the ATS coal bunkers is to be coordinated with the Corette plant coal bunker filling operations. Prepared coal can be available for

startup of the MHD power train by prior activation of the coal preparation system. Coal for bunker refilling activities will require specific coordination, and the Corette plant utility superintendent would have the ultimate responsibility for fuel distribution.

After obtaining a bulk supply of seed material the operational aspects of feeding the seed to the MHD power train would be accomplished by a sequential system startup procedure.

The oxidizer system which includes the manufacturer of liquid oxygen and liquid nitrogen can be started and operated independently of the other systems. Sufficient quantities of liquid oxygen and nitrogen to support the startups of the SCM and coal preparation areas can be manufactured prior to these startup activities. During the MHD power train operation the requirement for oxidant will be satisfied from the liquid oxygen storage and the blend air compressor.

Both liquid and solid effluent handling systems will require coordination for disposable requirements to prevent operational conflicts between the two plants.

The auxiliary systems that have a direct or secondary interface with the MHD power train or its auxiliary equipment are: 1) the water systems; 2) auxiliary fuel; 3) compressed air; and 4) heating/ventilating requirements. All of these systems either obtain their input from the existing Corette plant or operate independently within the ATS facility. As

such, these systems operation will be integrated into startup, transient or normal operations by use of the supervisory control system.

The particulate control device would be activated and operate in concert with the HRSR as it is brought up to operating conditions. Disposal of fly ash will require total plant coordination to prevent operational interference.

The substation and transmission lines will be energized and require no other action to provide the power requirements as necessary for operation.

2.6.3 Interface Systems

As long as the Corette plant is operating, the steam, feedwater, and water systems will be operational and require minimum coordination to interface with the ATS, when operation is accomplished with the supervisory control system.

Instrumentation and controls are effectively managed by the supervisory control system. The electrical system is operational once the main switch from the 100 KV ring bus is energized and should require no additional operational adjustment.

The buildings and structures for the ATS facility can remain an autonomous island adjacent to the existing Corette plant. Access will not be restricted to the ATS but it is expected that there will be minimum interaction except for the supervisory control.

2.6.4 System Integration

As discussed in previous sections, the true integration of the ATS with the Corette plant is through the interfaces of the steam, feedwater, water, and fuel systems. The use of supervisory control in the instrumentation and control systems will successfully integrate the two operating systems, especially when ultimate responsibility is given to the Corette plant utility superintendent. Starting and loading of the various ATS systems will require coordination between the plants to alleviate unnecessary starts or delays in the operation of the ATS. High motor starting loads are especially susceptible to power grid operating conditions.

2.6.5 Special Conditions

There are only a few special operational conditions that require consideration beyond those of a normal coal-fired power generating plant.

One is that to prevent any possibility of spontaneous ignition of dried and pulverized coal the prepared coal storage bin should be completely run empty at the conclusion of MHD power train operations. Another would be the general awareness that liquid oxygen is an impact sensitivity material and if brought into contact with hydrocarbon compounds can be highly dangerous when improperly handled. The final caution is that there should be restricted access in the highly energized field generated around the SCM.

Close attention must be given to the quantity and quality of the two high-pressure superheated steam supplies. The supervisory control will function to minimize these differences but operator awareness could prevent many operational problems from developing into major control excursions.

Various tests, as well as maintenance and inspection shutdowns, may be expected at a greater frequency than at a conventional steam plant. These activities will be coordinated through, and controlled by the utility superintendent.

3.0 ENVIRONMENTAL REQUIREMENTS

Retrofit of an existing power plant with an MHD system will require that applicable environmental regulations be followed. Depending on local and state regulations, and the ownership of the MHD system (federal or private) certain siting, air quality, water quality, solid waste, and health and safety regulations will have to be met. These regulations are summarized in Table 3-1. In the following text the environmental considerations for the following MHD retrofit scenarios are discussed:

- MHD retrofit of the MPC Corette Plant, Billings, Montana; DOE ownership of new hardware;
- MHD retrofit of any coal-fired power plant in Montana; private ownership of new hardware; and
- MHD retrofit of a coal-fired power plant anywhere in the country; private ownership of new hardware.
- MHD retrofit of a coal-fired power plant anywhere in the country; DOE ownership of new hardware. This scenario is identical to that described for private ownership of new hardware.

3.1 Site Requirements/NEPA-MEPA

3.1.1 Montana Regulations

Figure 3-1 summarizes the Major Facilities Siting Act, MEPA, and NEPA process described below. The procedural requirements of the Montana Major Facilities Siting Act (MMFSA), 75-20-101, et. seq. M.C.A., will not apply to a federally

			ACTIVITY									
TITLE	LAW	RESPONSIBLE AGENCY	Federal EIS	State EIS	Siting	Water Appropriation	Water Discharge	Dredge and Fill	Construction	Solid Waste	Air Emissions	Operation
National Environmental Policy Act (NEPA)	42 U.S.C. 4321 et. seq.	DOE (if federally owned)	X									
Montana Environmental Policy Act (MEPA)	75-1-101 et. seq. M.L.A.	DNRC or DHES		X								
Montana Major Facilities Siting Act (MMFSA)	75-20-101 et. seq. M.L.A.	DNRC			X							
Montana Water Use Act (MWUA)	85-2-301 thru 314. M.L.A.	DNRC				X						
Montana Water Quality Act (MWQA)	75-5-101 et. seq. M.L.A.	DHES					X		X			
Federal Clean Water Act (FCWA)	33 U.S.C. 1344 Section 401	DHES for EPA					X		X			
Federal Clean Water Act (FCWA)	33 U.S.C. 1344, Section 404	COE for EPA						X	X			
Montana Solid Waste Management Act (includes hazardous waste)	74-10-201 et. seq. M.C.A.	DHES							X	X		
Federal Resource Conservation and Recovery Act	42 U.S.C. 6901 et. seq.	DHES and EPA							X	X		
Montana Clean Air Act	75-2-101 et. seq. M.C.A.	DHES							X		X	
Federal Clean Air Act	42 U.S.C. 1857 et. seq.	DHES for EPA							X		X	
Federal Occupational Safety and Health Act	29 U.S.C. 688 et. seq.	OSHA							X			X

Table 3-1 -- Major Environmental Laws Governing an MHD Retrofit of an Existing Power Plant in Montana

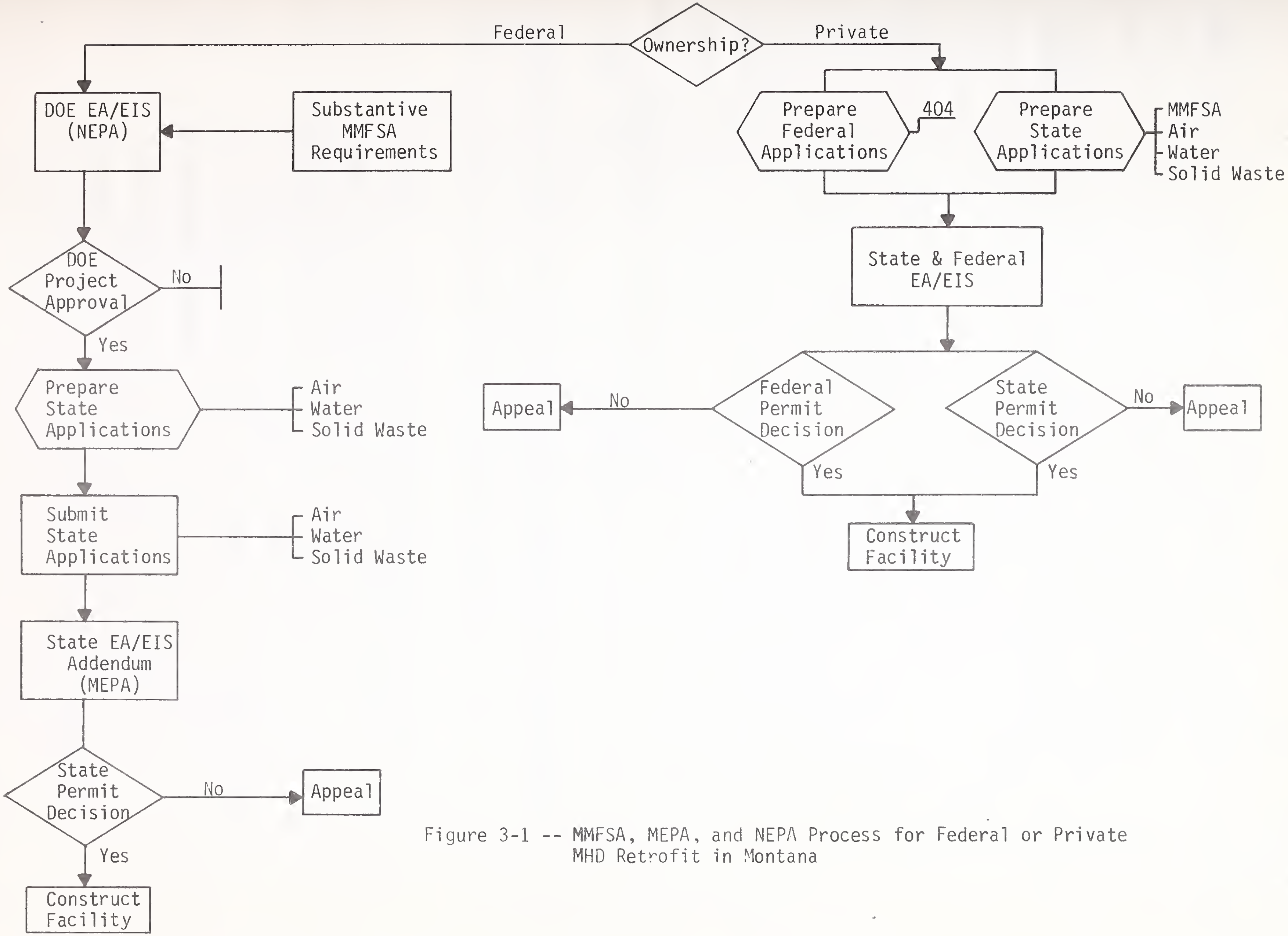


Figure 3-1 -- MMFSA, MEPA, and NEPA Process for Federal or Private MHD Retrofit in Montana

owned retrofit of the MPC Corette Plant, Billings, Montana. The MMFSA, Section 75-20-202(1) M.C.A., specifically exempts "...any aspect of a facility over which an agency of the federal government has exclusive jurisdiction." However, there is a question of whether or not substantive requirements of the act will have to be met. The question of meeting substantive requirements of the act has been raised by a recent ruling by federal Judge James Battin that the Bonneville Power Administration must meet the substantive requirements of the act for a transmission facility being built in Montana. This ruling was based on a requirement of federal law that federal facilities must meet all state and local regulations. The actual substantive requirements that would have to be met would be determined by the Board of Natural Resources and Conservation. There would be a possibility of waivers for certain requirements as, under certain conditions, the board may adopt reasonable rules establishing exemptions from the MMFSA (75-20-202(3) M.C.A.).

The MMFSA will apply to a privately owned MHD retrofit of an existing power plant in Montana. MMFSA parts that support this conclusion include:

- 5-20-104(1) "Addition thereto" means the installation of new machinery and equipment which would significantly change the conditions under which the facility is operated; and
- 75-20-104(10a) "Facility" means ...each plant, unit, or other facility and associated facilities designed for or capable of: (i) generating 50 megawatts of electricity or more or an addition thereto (except pollution control facilities approved by the Department of Health and Environmental Sciences added to an existing plant) having an estimated cost in excess of 10 million.

For a privately owned facility both the procedural and substantive requirements of the MMFSA would have to be met. The applicable requirements of the MMFSA include:

- Inclusion in a ten year plan;
- Notice of intent to file an application;
- Environmental and Engineering studies;
- Application for a certificate which includes results of the environmental and engineering studies;
- Payment of an application fee;
- DNRC study of application and report to the Board (DNRC EIS);
- Board of Natural Resources and Conservation hearing; and
- Board of Natural Resources and Conservation decision to grant or deny certification.

Certain requirements of the MMFSA could be waived by the Board for an MHD retrofit pursuant to 75-20-202(3) M.C.A.

The Montana Environmental Policy Act (MEPA) 75-1-01 et. seq. M.C.A. will apply to any MHD retrofit of an existing power plant in Montana. If the retrofit will be federally owned then the probable state lead agency will be the Department of Health and Environmental Sciences (DHES) as this agency will be responsible for granting air, water, and waste disposal permits. Application of MEPA in this scenario would require DHES to perform an Environmental Assessment (EA) or to write an Environmental Impact Statement on the effects of granting the required permits. Further discussion of the air, water, and waste disposal permits is found in later sections of this

report. If a federal EIS has been written on the project then MEPA allows the state to incorporate the federal EIS by reference; thus allowing the state EIS to take the form of an addendum.

If the retrofit will be privately owned then DNRC will be the lead state agency due to the umbrella effect of the MMFSA. MEPA would require DNRC to write an EA or EIS on the effects of granting a certificate of Public Need and Environmental Compatibility to the utility. If a federal EIS has been written then DNRC would be able to prepare an addendum to fulfill its MEPA requirements.

The EIS must contain the same type of information no matter which state agency prepares it. The EIS must:

- Describe the environmental impact of the proposed action (action taken by the state agency such as granting the permit);
- Describe any adverse environmental effects which cannot be avoided should the action be taken;
- Describe alternatives to the proposed action;
- Describe the relationship between local short-term uses of man's environment and maintenance and enhancement of long-term productivity; and
- Describe any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

3.1.2 Federal Regulations

There are no national laws or regulations governing the siting of MHD retrofits of existing power plants. However, the identification and comparison of alternatives as required by the National Environmental Policy Act (NEPA) 42 U.S.C. 4321 et.seq. essentially requires a siting study.

NEPA requires that a federal agency proposing a specific action perform an environmental assessment (EA) to determine if the effects of the proposed action will have significant impact on the human environment. If a positive determination is made then the federal agency must prepare an Environmental Impact Statement (EIS). The State EIS format and content described earlier were patterned after the federal requirements; therefore, a federal EIS will contain the same information as described for the State EIS.

There are two MHD retrofit scenarios that would require a federal EIS. If the proposed retrofit of the MPC Corette Plant in Billings will be federally owned then DOE will be required to perform a NEPA EA and/or EIS. A privately owned retrofit of an existing power plant in Montana may not require a federal EA or EIA as all major permits are obtained from the State DNRC-DHES. A federal EIS would be necessary in this case only if one of the minor federal permit (such as the Corp of Engineers 404 dredge and fill permit) environmental assessments found that a significant impact to the human environment would occur as a result of the granting of the permit. A federal EA and/or EIS would be required in other states for a privately owned MHD retrofit if a state did not operate federally approved air and water quality programs. In a state where the Environmental Protection Agency (EPA)

operates the air and water quality permit system then EPA will be responsible for meeting the EIS requirements of NEPA. This process is shown in Figure 3-2.

3.2 Air Quality

An MHD retrofit to any facility whether owned privately or by DOE must comply with three different, but related, types of air quality regulations. These are the New Source Performance Standards (NSPS) regulating point sources, State and Federal Ambient Air Quality Standards, and Prevention of Significant Deterioration (PSD) regulations. These three sets of air quality regulations are discussed in the following text in regard to their application to the design of an MHD retrofit facility, particularly the Corette case.

All air quality permitting for a major facility in Montana, such as the MHD retrofit, is administered through the Department of Health and Environmental Sciences - Air Quality Bureau. Permitting for both federal and State of Montana requirements is handled jointly since Montana has EPA approved programs for administering all permitting required by the Federal Clean Air Act. Yellowstone County's air quality regulations are not applicable to major facilities such as the proposed MHD retrofit. Consequently, only State of Montana and federal requirements will be discussed.

3.2.1 New Source Performance Standards

One goal of an MHD retrofit, whether owned by the Government or a utility, is to demonstrate that the technology complies with the emission control

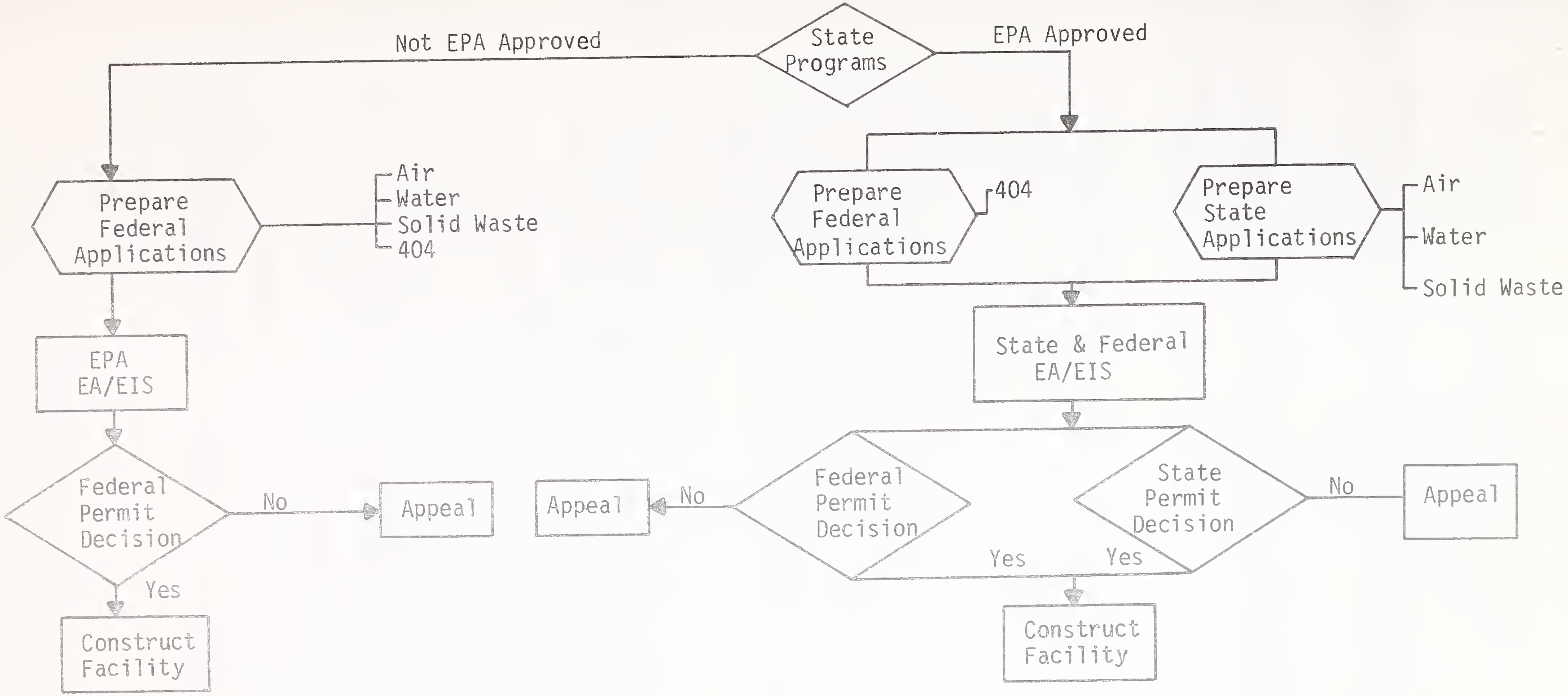


Figure 3-2 -- NEPA Process in States Other Than Montana for a Privately Owned Retrofit

regulations for coal-fired electric utility units. These regulations, shown in Table 3-2, apply to units constructed for the purpose of supplying more than one-third of its "potential electric output capacity" (defined as 33% of the maximum design heat input capacity) and more than 25 MW_e output to any utility power distribution system for sale. The Corette retrofit clearly meets these criteria thus the design considerations for emission control are based upon the standards in Table 3-2.

The NSPS for particulates will require either a highly efficient electrostatic precipitator (ESP) or baghouse. Based on the material balance of ash, slag, and potassium seed material for the MHD process stream the collection efficiency of either device must be a minimum of 99.5% at the expected inlet loading of 5,000 lb/hour. This requirement is based on slag rejection rate accomplishing 85% ash removal at the combustor with about half of the remaining ash, slag, and seed being removed in the radiant furnace and convective sections.

Based on either requirements for Best Available Control Technology (BACT) or Lowest Achievable Emission Rate (LAER) mandated for new facilities by federal and Montana regulations, fabric filtration control is the recommended method based on the current state of the art. High collection efficiency over the entire range of particle size and generally lower cost than electrostatic precipitators makes this option appear more favorable. Another disadvantage of using an ESP for this retrofit facility is uncertainty in both the chemical characteristics and size distribution of particulate which must be controlled. Detailed knowledge of these chemical and physical parameters are

TABLE 3.2

NEW SOURCE PERFORMANCE STANDARDS (AIR) FOR ELECTRIC UTILITY STEAM GENERATING UNITS (44 FR 33580)

Emissions Limits for Coal-Fired Units

Particulates

13 ng/J (0.03 lb./MBtu)

20% opacity (except for one 6-minute period per hour of not more than 27% opacity)

SO_2

520 ng/J (1.2 lb./MBtu)*

90% reduction except 70% reduction when emissions are less than 26 ng/J (0.6 lb./MBtu)*

NO_x

Subbituminous coal, shale oil, fuel derived from coal: 210 ng/J (0.5 lb./MBtu)*

*30-day rolling average

essential to the design and sizing of an ESP. The proposed facility could provide an opportunity for obtaining much of this data which is not currently available from existing MHD test facilities.

The NSPS for SO_2 requires 90% control of potential SO_2 emissions based on the sulfur content of the coal being used. An upper limit of 1.2 lb SO_2 per 10^6 Btu is allowed but the requirement is relaxed to 70% control if emissions are less than 0.6 lb per 10^6 BTU as indicated in Table 3.2. For the reference Rosebud coal being used for design purposes, 70% control of sulfur will satisfy the NSPS requirements, limiting potential emissions to 0.6 lb SO^2 per 10^6 BTU. This requirement should be easily met by using the appropriate amount of K_2CO_3. For once through seed usage (no recycling or regeneration) a minimum of 30% of the necessary potassium should be K_2CO_3 to achieve the 70% reduction and 0.6 lb per 10^6 BTU emission requirements. The remaining potassium can be added as some less expensive form such as K_2SO_4.

For any general case for MHD requiring more stringent control of SO_2, the proportion of K_2CO_3 can be increased with virtually total elimination of SO_2 emissions, if deemed necessary. This feature of MHD is unique and can play an important role in the siting of an MHD facility, particularly in areas where regulatory constraints severely limit the allowable emission of SO_2.

The NO_x emission requirement of 0.5 lb. per 10^6 BTU must be met by fuel rich initial combustion stoichiometry (0 = .95) at the MHD combustor followed

by secondary combustion in the radiant furnace at a lower temperature with sufficient residence time at appropriate temperatures to allow relaxation of NO_x to acceptable NSPS levels.

To meet the NSPS described in this section maximum emissions from the Corette MHD retrofit will be limited to the following:

Particulates	26 lb/hour (.03 lb/10^6 BTU)
SO_2	514 lb/hour (.6 lb/10^6 BTU)
NO_x	428 lb/hour (.5 lb/10^6 BTU)

These values can be used in dispersion models appropriate to the plant setting to determine if all ambient air quality standards and prevention of significant deterioration (PSD) regulations are being met at maximum allowable emission rates. PSD and ambient regulations and their possible influence on emission control are discussed in the following Sections 3.2.2 and 3.2.3.

3.2.2 Ambient Air Quality Standards

Federal Ambient Air Quality Standards are shown in Table 3.3 and Montana Ambient Air Quality Standards are shown in Table 3.4. Notwithstanding the NSPS discussed in Section 3.2.1 and the PSD increments discussed in Section 3.2.3, these ambient concentrations cannot be exceeded. The Federal standards apply to facilities anywhere in the country. State standards vary considerably depending on the locality but, in all cases are at least as stringent as the Federal standard.

TABLE 3.3

NATIONAL AMBIENT AIR QUALITY STANDARDS[a]

	Primary Standard	Secondary Standard
Particulate		
24-hour average	260 μg/m^3[b]	150 μg/m^3[b]
Annual geometric mean	75 μg/m^3	60 μg/m^3
Sulfur Dioxide		
3-hour average	- -	0.5 ppm (1300 μg/m^3)[b]
24-hour average	0.14 ppm (365 μg/m^3)[b]	- -
Annual average	0.03 ppm (80 μg/m^3)	- -
Carbon Monoxide		
1-hour average	35 ppm (40 mg/m^3)[b]	35 ppm
8-hour average	9 ppm (10 mg/m^3)[b]	9 ppm
Ozone		
1-hour average	0.12 ppm (235 μg/m^3)[b,c]	0.12 ppm
Nitrogen Dioxide		
Annual average	0.05 ppm (100 μg/m^3)	0.05 ppm
Lead		
Calendar quarter	1.5 μg/m^3	1.5 μg/m^3
Hydrocarbons		
3-hour concentration	0.24 ppm (160 g/m^3)[d,b]	- -

a. 40 CFR Part 50
b. Not to be exceeded more than once per year
c. 44 FR 8202
d. Guideline only

TABLE 3.4

MONTANA AMBIENT AIR QUALITY STANDARDS

(Montana Department of Health and Environmental Sciences,
Air Quality Rules, 1982)

CO	
8-hour average	9 ppm*
Hourly average	23 ppm*
H_2S	
Hourly average	.05 ppm*
Lead	
Calendar quarter average	1.5 $\mu g/m^3$
NO_2	
Hourly average	0.30 ppm*
Annual average	0.05 ppm
Ozone	
Hourly average	0.10 ppm*
Settled Particulate Matter	
30-day average	10 $\mu g/m^2$
SO_2	
Hourly average	0.50 ppm**
24-hour average	0.10 ppm*
Annual average	0.02 ppm
Suspended Particulate Matter	
24-hour average	200 $\mu g/m^3$*
Annual average	75 $\mu g/m^3$

Visibility

Annual average particle scattering coefficient of 3 x 10^{-5}/m. Applicable only to designated PSD Class I areas.

*Not to be exceeded more than once per year.
**Not to be exceeded more than 18 times in any 12 consecutive months.

Whether these ambient standards or the PSD increments in Section 3.2.3 are limiting constraints depend on the specific locality of the proposed facility and the existing baseline ambient air quality in the region. In general, PSD increments are the limiting factors for particulates and SO_2 unless baseline concentrations are near, but not exceeding, the ambient standard.

If Federal ambient standards are already exceeded, the area is designated a non-attainment area for specific pollutants. In such non-attainment areas, new sources would not be allowed unless a corresponding decrease in the pollutant of concern is achieved in the area. This is referred to as emission offset and the applicant for a permit must provide for reduction in existing emissions of the non-attainment pollutant in the area sufficient to achieve an improvement in ambient concentrations of that pollutant, even after the new source is in operation.

3.2.3 Prevention of Significant Deterioration (PSD)

The Federal Clean Air Act sets PSD increments for SO_2 and particulates as shown in Table 3.5. These increments are measured against a baseline determined by the date of the first PSD permit application in the air quality control region.

Pollutant category of the proposed facility will be that of "major source" for both SO_2 and particulate. "Major source" is defined for these purposes as having potential emissions exceeding 40 tons per year of SO_2 or 25 tons per year of particulate.

TABLE 3.5

PREVENTION OF SIGNIFICANT DETERIORATION IN AIR QUALITY: ALLOWABLE INCREMENTS IN μg/m^3 (43 FR 26405)

Pollutant*	Class I	Class II	Class III
Particulates:	ug/m(3)		
Annual geometric mean	5	19	37
24-hour average	10	37	75
SO_2			
Annual arithmetic mean	2	20	40
24-hour average	5	91	182
3-hour maximum	25	512	700

*All values other than annual averages may be exceeded once per year.

*No pollutant concentrations may exceed national ambient air quality standards.

Once a source is determined to be a major source for any pollutant for which ambient standards currently are being met, PSD review applies to all pollutants which will be emitted by the source. These requirements include, as a rule, one year of pre-application monitoring of ambient air quality, and an air quality impact analysis based on monitoring or modeling, to determine the extent of anticipated impacts of the facility on ambient air quality. In addition, BACT would be required for all pollutants.

If the results of the PSD review and modeling warrant, control requirements more stringent than the NSPS discussed in Section 3.2.1 could be mandated. As mentioned previously, the MHD process has the capability of meeting virtually any SO_2 control requirement particularly when low-sulfur coal is used.

The existing Corette facility is located in an area where ambient SO_2 concentrations are near or exceed ambient standards. It is possible that the area could be designated a non-attainment area for SO_2. If this occurs, nearly total removal of SO_2 emission could be required. Even if the area is not so designated, very little increment remains between baseline concentrations and the allowable ambient concentrations.

SO_2 appears to be the only ambient standard which will significantly influence design requirements for an MHD retrofit to the Corette facility. The MHD process as designed should meet the Class II PSD increments for particulate and the ambient NO_x Standards when operating at the maximum allowable NSPS mission rates described in Section 3.2.1. A detailed modeling study will be required as part of the PSD permit and air pollution discharge permit to demonstrate quantitative compliance with these regulations.

The general air quality permit process which must be followed is shown in Figure 3.3. If submitted under the Montana Major Facility Siting Act, all applications will be through DNRC to the DHES. The indicated permits will be submitted as an integral part of the application to DNRC.

3.3 Water Quality

3.3.1 Montana Regulations

In Montana, the ownership (federal or private) of an MHD retrofit to an existing power plant would not affect the applicability of the water pollution control regulations; therefore, the following discussion is applicable to a federally or privately owned retrofit of the Corette plant in Billings, Montana or a privately owned retrofit of any other power plant in the State.

The Montana Department of Health and Environmental Sciences (DHES) administers the Montana Pollution Discharge Elimination System (MPDES). In order for an entity (private or public) to discharge liquid wastes into surface waters of the state, the entity must obtain a MPDES permit from DHES. Information required in the permit application includes:

- o Background flow and quality information on the receiving stream;
- o Quality and flow information on the discharge;
- o Process and treatment information; and
- o Map(s) of point(s) of discharge.

The MPDES was established by the Montana Water Quality Act 75 -5-101 et.seq. M.C.A. and the administrative rules are found at 16.20.901-919, A.R.M.

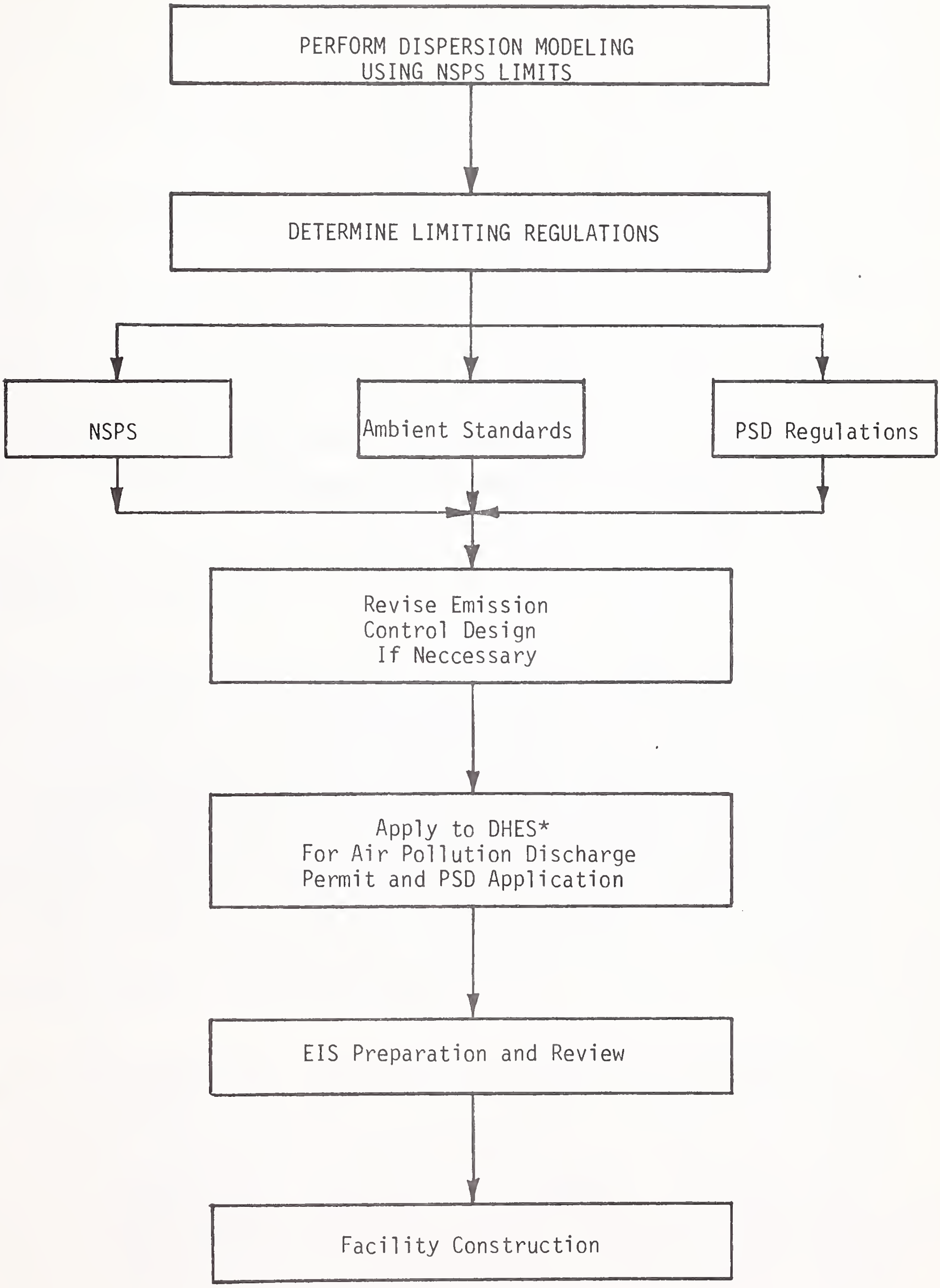

PERFORM DISPERSION MODELING USING NSPS LIMITS
DETERMINE LIMITING REGULATIONS
NSPS
Ambient Standards
PSD Regulations
Revise Emission Control Design If Neccessary
Apply to DHES* For Air Pollution Discharge Permit and PSD Application
EIS Preparation and Review
Facility Construction

Figure 3-3 -- Air Quality Permitting Process

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*May be formally submitted to DNRC if the Major Facility Siting Act is followed; DHES will review in any case.

When a currently operating facility, such as the Corette plant, is discharging under an existing MPDES permit then the addition of the MHD retrofit will require either a brand new permit, if a new discharge will occur, or a permit modification, if the waste water from the new retrofit facility will be handled by the existing waste water handling system. Differences between these cases are mostly procedural as the data required for a permit modification is similar to that required for a new permit. The Corette water and waste handling systems are operating at capacity now; therefore, a retrofit of the Corette plant will require new discharge permits for any releases to the Yellowstone River (see Section 2.2.4). Existing limitations on the Corette discharge permit indicate that the MHD retrofit may have to remove all heat from cooling water releases. The MPDES process is summarized in Figure 3.4.

Since Montana operates an EPA approved water quality program, DHES issues the Section 401 (of the Federal Clean Water Act) permit. This permit is only issued if the project requires other federal permits and will discharge into navigable waters. The permit is a certification by DHES that the discharge will comply with the applicable provisions of the Federal Clean Water Act, Sections 301, 302, 303, 306, and 307. Information needs on the application are similar to those for the MPDES permit.

A permit to appropriate water, obtained from the Montana Department of Natural Resources and Conservation, may be required for an MHD retrofit of an existing plant (Montana Water Use Act 85-2-301- et.seq.). An appropriation permit will only be required if the sum of the water required to operate the MHD addition and the water required to operate the existing plant will exceed

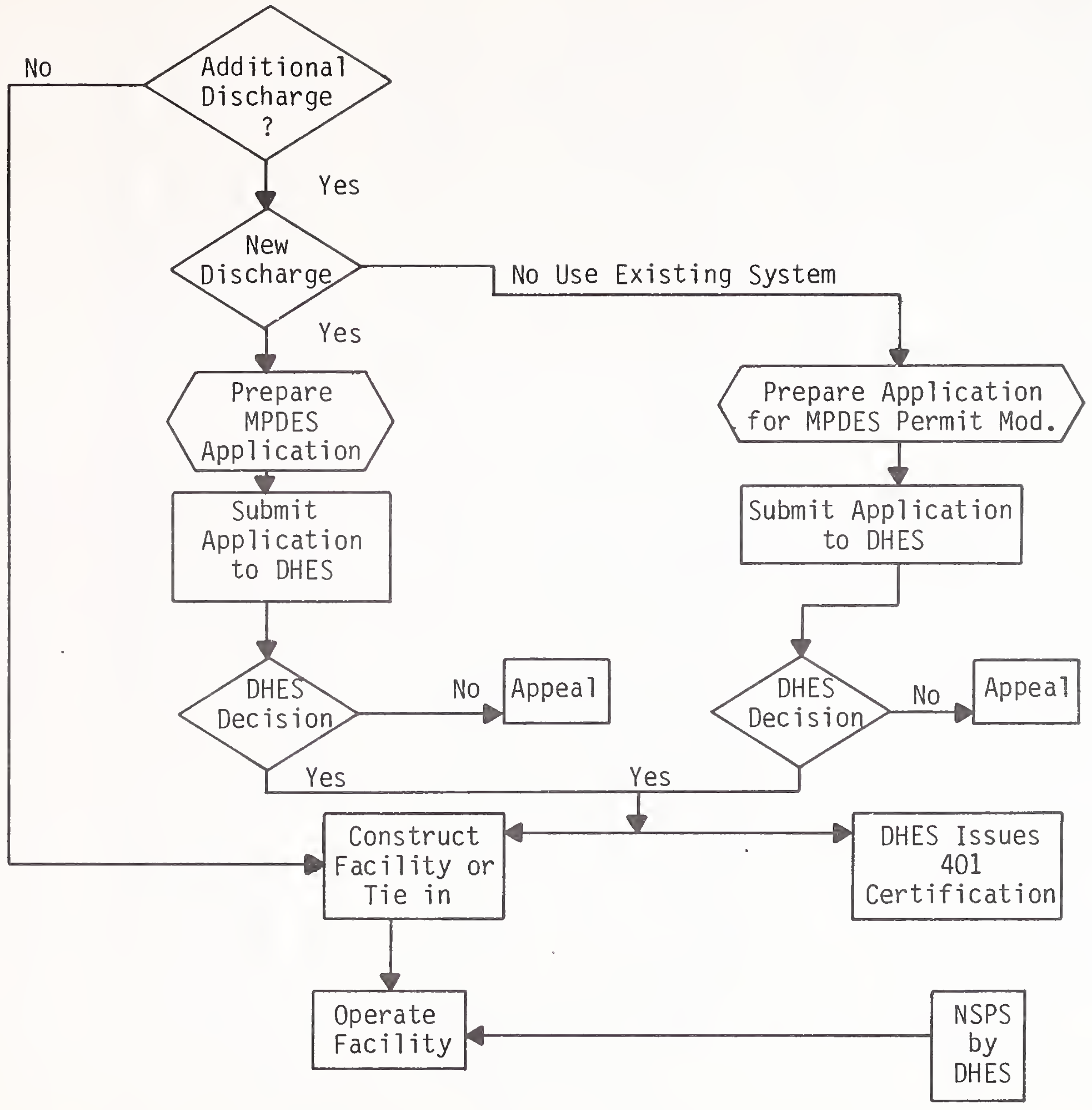

No
Additional Discharge ?
Yes
New Discharge
No Use Existing System
Yes
Prepare MPDES Application
Prepare Application for MPDES Permit Mod.
Submit Application to DHES
Submit Application to DHES
DHES Decision
No
Appeal
DHES Decision
No
Appeal
Yes
Yes
Construct Facility or Tie in
DHES Issues 401 Certification
Operate Facility
NSPS by DHES

Figure 3-4 -- Process Diagram For Application Of MPDES And NSPS Regulations For Water For An MHD Retrofit Of An Existing Power Plant In Montana

the currently held water appropriation. According to engineering estimates concerning water for an MHD retrofit to the Corette Plant in Billings the sum of the additional water needs plus existing water needs will not exceed the present MPC appropriation. (See Sections 2.2.4 and 2.3.3). The appropriation process is summarized in Figure 3-5.

The Montana DHES, Water Quality Bureau, enforces the national New Source Performance Standards (NSPS) for water. The standards for steam-electric generating units, found in 40 CFR, Parts 125 and 423, dictate the allowable levels of certain parameters in the waste streams. Limitations are listed for effluents, once-through cooling water and cooling tower blowdown, area run-off, and pre-treatment for sewer system releases. If a new coal preparation plant is constructed as part of the new facility, then the New Source Performance Standards (found in 40 CFR Part 434.20) will control levels of certain parameters in the runoff from the facility.

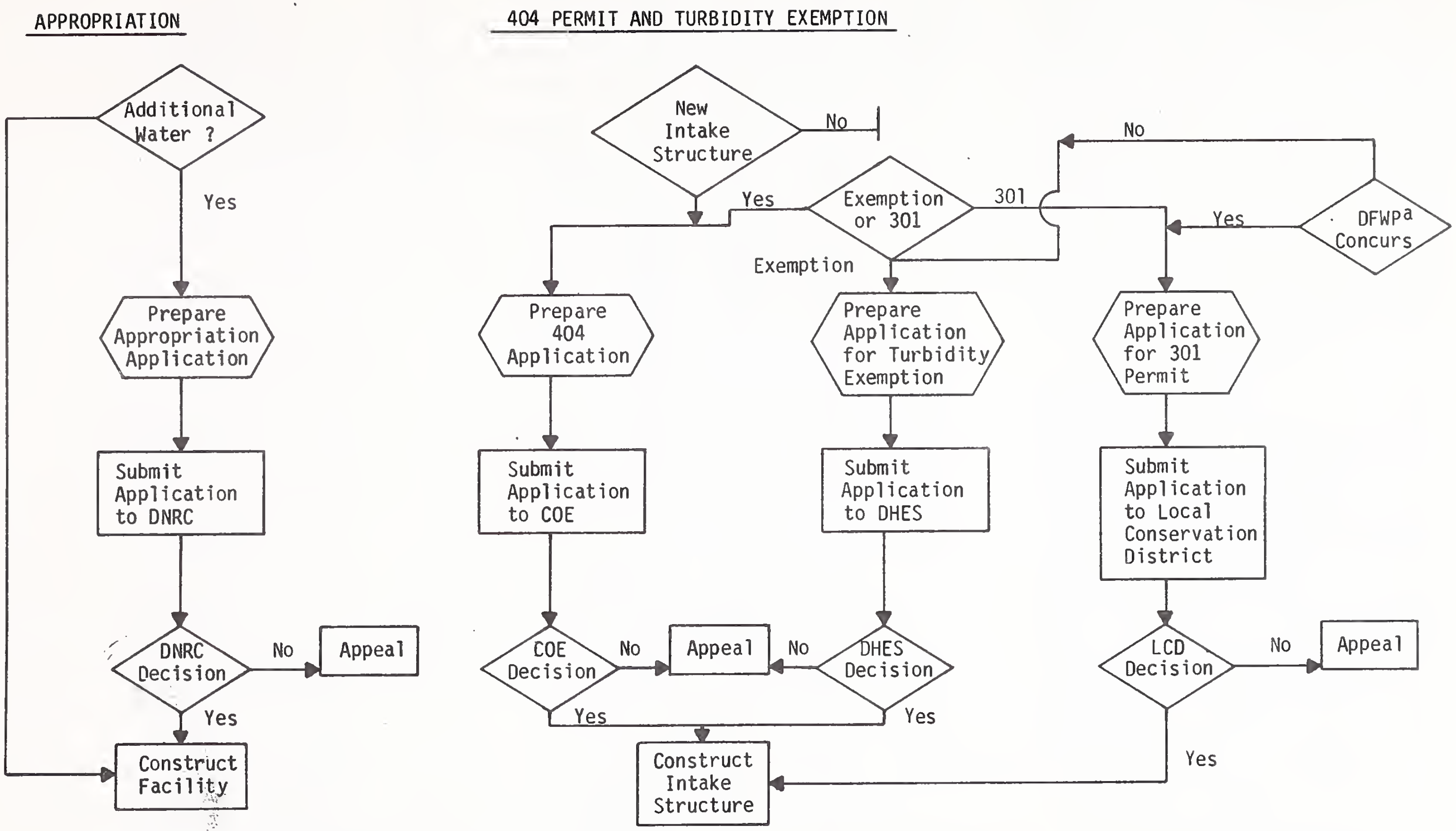
An authorization for Short-Term Exemption From Surface Water Quality Standards, obtained from DHES, is required when there will be instream construction activities that cause turbidity standards for the stream to be exceeded. The MHD retrofit to the Corette Plant in Billings will probably not need this authorization as current engineering activity does not indicate the need for construction of a new intake structure, (see Section 2.3.3).

However, this authorization will be required for MHD retrofits of other power plants in Montana if construction activities take place instream. A waiver for this authorization is allowed if the following conditions are met: 1) the applicant obtains a 310 permit from the Local Conservation District (see

Section 3.5.1 of this report); and 2) the Montana Department of Fish, Wildlife, and Parks concurs with the waiver. The exemption process is summarized in Figure 3.5.

3.3.2 Federal Regulations

A 404 Permit, obtained from the U.S. Army Corps of Engineers, is required for a project if dredge and fill activities occur either in a stream with a flow greater then 5 cfs or in a wetland. In the case of the retrofit of the Corette plant, a 404 Permit will probably not be required. The current engineering plans indicate the water for the MHD facility will be obtained without building an additional intake structure (the major potential activity requiring dredge and fill).


APPROPRIATION
Additional Water ?
Yes
Prepare Appropriation Application
Submit Application to DNRC
DNRC Decision
No
Appeal
Yes
Construct Facility
404 PERMIT AND TURBIDITY EXEMPTION
New Intake Structure
No
Yes
Exemption or 301
301
Exemption
No
Yes
DFWPa Concurs
Prepare 404 Application
Prepare Application for Turbidity Exemption
Prepare Application for 301 Permit
Submit Application to COE
Submit Application to DHES
Submit Application to Local Conservation District
COE Decision
No
Appeal
No
DHES Decision
Yes
Yes
LCD Decision
No
Appeal
Yes
Construct Intake Structure

[a]DFWP = Department of Fish, Wildlife, and Parks

Figure 3-5 -- Process Diagrams For 404 Permit, Turbidity Exemptions, And Water Appropriation Regulations In Montana Applicable To An MHD Retrofit

For other MHD retrofit projects, either within Montana or nationally, the construction of an additional intake structure would be the major activity requiring a 404 permit. Figure 3-5 summarizes the 404 permit process.

In Montana, and other states with EPA approved water quality control programs, the recognized state agency is responsible for administering the National Pollution Discharge Elimination System (NPDES), the Section 401 Permit (certification), and the New Source Performance Standards (NSPS) for water. These permits, certifications, and standards would apply to an MHD retrofit of an existing plant as previously described. In states without EPA approved programs the State EPA office administers these permits.

3.4 Solid Waste

Solid wastes (such as slag, ash, and spent seed) from an MHD retrofit must be disposed in a manner which complies with all applicable regulations. Solid wastes are classified as hazardous or non-hazardous based on characteristics of the waste. Each type is regulated by separate regulations at the state and national level. Section 2.4.4 of this report describes the proposed waste handling systems for the Corette retrofit.

3.4.1 Montana Regulations

Application of the Montana Solid Waste Management Act 74-10-201 et. seq. M.C.A. to an MHD retrofit of an existing power plant in Montana is not dependent on ownership (federal or private) of the retrofit hardware. Application of solid waste disposal regulations in Montana is summarized in Figure 3-6.

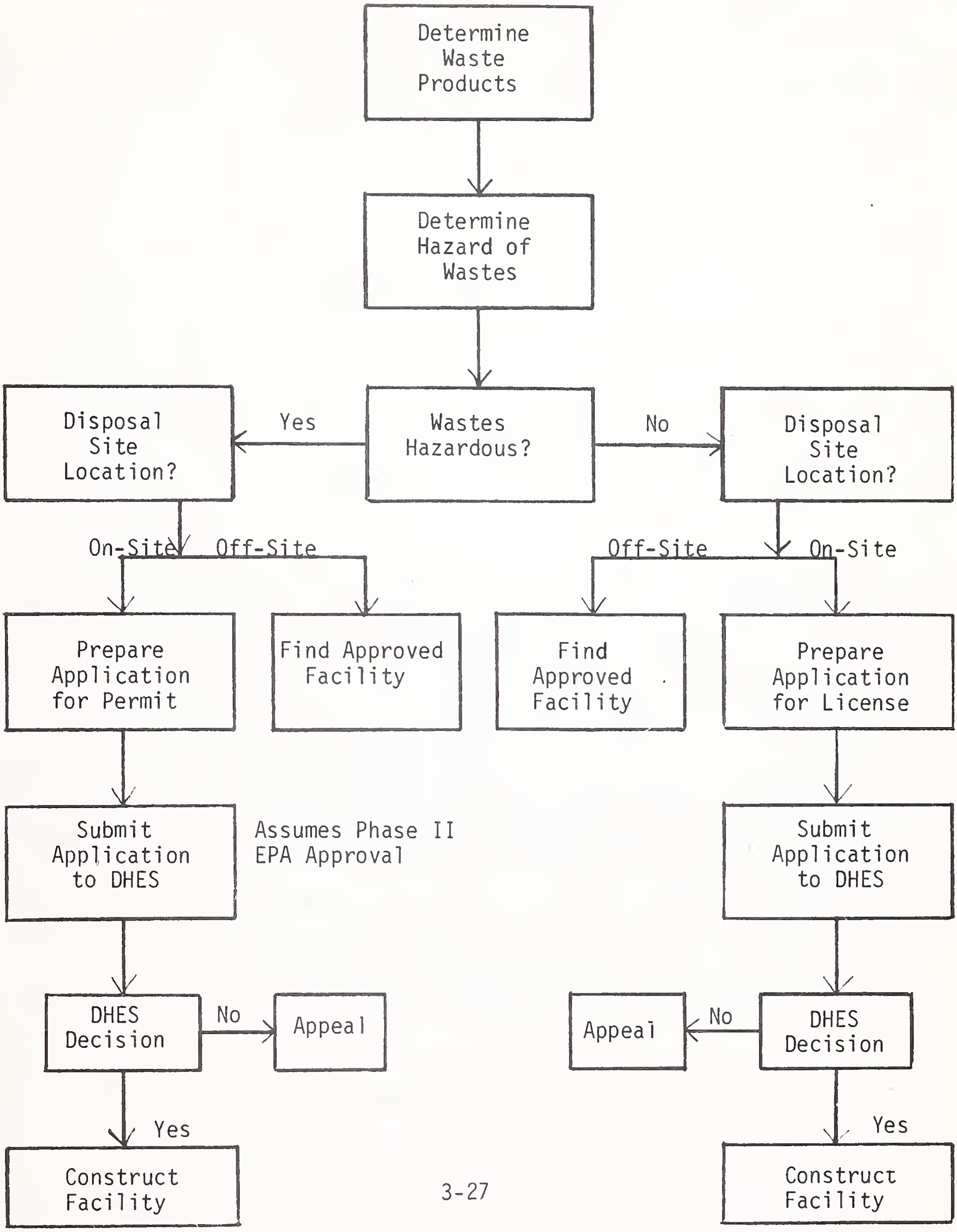


Figure 3-6 -- Application Of Solid Waste Disposal Regulations To An MHD Retrofit Of Power Plants In Montana

Montana has obtained EPA Phase I approval of its hazardous waste management program. This approval gives Montana, administered by the Department of Health and Environmental Sciences, the primary authority to regulate generators and transporters of hazardous waste. Phase II approval, expected by the end of 1983, will give Montana the primary authority to regulate hazardous waste treatment, storage, and disposal facilities.

Some wastes, such as fly ash, bottom ash, slag, and flue gas wastes, from conventional power plants are specifically listed as nonhazardous and are exempt from the regulations. However, due to the status of MHD as a new technology, wastes produced from an MHD plant would probably have to be tested for hazardous or nonhazardous classification. The Montana (and EPA) regulations require testing of solid wastes not specifically exempted for their ignitability, flammability, reactivity, and EP toxicity according to named procedures. The test results would be reported to DHES for confirmation. A recent article in Environmental Science and Technology (Dahlberg 1983) reports that bottom ash slags and fly ash slags from an MHD test facility were found to be non-toxic using the Extractional Procedure Toxicity method. Dahlberg (1983) concluded the bottom ash slags and fly ash slags from the test facility were nonhazardous. However, further testing of all MHD produced solid wastes would probably be required before the Montana DHES or EPA would make a ruling on the hazardous nature of the waste.

If any MHD wastes are found to be hazardous according to the tests or are specifically listed as hazardous they would be regulated by DHES. Generators of hazardous wastes receive an ID number from the regulatory authority and are required to file information as to the nature, volume, and disposition of

the waste. Recordkeeping, container labeling, and manifest systems for transport are also the responsibility of the hazardous waste generator.

If the MHD retrofit owner (private or federal) wishes to treat, store, or dispose of hazardous wastes produced by the plant on site, then a permit from DHES (after Phase II approval by EPA) would be required. Information required for the permit application includes:

- Name and business address of applicant;
- Location of proposed facility;
- The operation and maintenance plans;
- The types of wastes to be handled; and
- A description of pertinent site characteristics.

Both those solid wastes determined to be nonhazardous by testing, and those listed as nonhazardous are also regulated. Disposal of nonhazardous solid wastes requires a license from DHES. The owner of the MHD retrofit would have to submit an application for a license if nonhazardous wastes will be disposed of on-site. Application information includes:

- Applicants name and address;
- Legal and general description of the facility;
- Total acreage of site;
- Pertinent water quality information;
- Geological and soil information;
- Present land use;
- Zoning of site; and
- Proposed operating and maintenance plan.

If the MHD retrofit owner decides to dispose of nonhazardous material off-site then a facility licensed to handle the wastes will need to be arranged or developed. Yellowstone County operates a Class II landfill which could legally handle nonhazardous MHD wastes from a retrofit of the Corette Plant; however, they could refuse to handle the wastes if the volume was excessive. Discussion with Yellowstone County officials should be initiated early in the final design phase to whether the amount of waste they would accept equates with the amount expected from the plant.

3.4.2 Federal Regulations

In those states where there is an EPA approved hazardous waste management program the process for controlling hazardous wastes is similar to that found in Montana. If wastes from MHD were found to be hazardous then disposal of MHD retrofit wastes in these states would follow the process shown in Figure 3-6. In those states without EPA approved solid waste programs all solid waste disposal (both hazardous and nonhazardous) is regulated by the EPA. The process in this case is similar to that shown in Figure 3-6 except that all applications for licenses or permits are submitted to EPA rather than a State agency. As the State programs were patterned after EPA regulations the EPA requirements are similar to those described for Montana.

3.5 Other Applicable Requirements

3.5.1 Local Regulations

Local (i.e. city and county) ordinances applicable to an MHD retrofit of an existing plant in Montana will vary from place to place; the following

discussion is valid only for the retrofit of the Corette plant in Billings, Montana. The following are regulated by local Yellowstone County ordinances.

- Air Quality;
- Waste Disposal - both solid and sewer;
- Alterations of streambeds or streambanks (310 Permit from Conservation District); and
- Flood Plain Development.

The Air Quality Control Board in Yellowstone County administers the local air quality control program. This program specifically exempts facilities that are regulated by the Prevention of Significant Deterioration (PSD) Rules administered by the Montana Department of Health and Environmental Sciences (DHES). The operation of the Corette retrofit would be regulated by the PSD rules (described in Section 3.2) and so would be exempt from local regulation.

Solid waste disposal in Yellowstone County and Billings is accomplished by dumping in a Class II landfill. This landfill could accept nonhazardous wastes from the MHD retrofit. However, if the volume of the waste is too great the landfill operator can refuse the material. Prior to final design of the plant solid waste disposal methods should be established. No local permits are required for on-site disposal of nonhazardous wastes but the local sanitarian must sign the state permit. (see Section 3.4.1).

Prior to hookup with the local sanitary sewer any new producer must obtain approval from the local sewer district. Before approval is granted the

applicant must show that the waste streams entering the sewer will not contain hazardous substance or material that would cause the treatment plant to fail. Since the MHD retrofit of the Corette plant will only discharge domestic wastes to the city sewer no problems in obtaining permission should be encountered.

The Local Conservation District (LCD) regulates alterations of streambeds or streambanks through the 310 Permit. An entity wishing to construct a project that would require an alteration to a streambed or streambank must apply for a 310 Permit from the LCD. However, since the Corette retrofit project will not need a new intake structure or discharge structure, this permit will probably not be needed.

Since the Corette plant is located on the floodplain of the Yellowstone River, the local floodplain regulations adopted by Yellowstone Board of County Commissioners would apply to an MHD retrofit of the Corette plant. These floodplain regulations require that the entity wishing to construct a structure within a 100 year floodplain submit an application to the Floodplain Administrator for a Floodplain Permit. This application must show:

- Name and Address of Applicant;
- Type of Structure to be built; and
- Location of Structure.

If the application shows that all standards for construction in a floodplain have been met then the administrator will grant the permit. The MHD retrofit

of the Corette plant will meet these standards; no problems should be encountered in obtaining these permits.

3.5.2 State Regulations

If a county in which an MHD retrofit is planned does not have a state approved County Floodplain Program, and, if the retrofit will take place on a 100 year floodplain, then the entity wishing to construct the facility must submit a floodplain application to the Montana Department of Natural Resources and Conservation (DNRC), Floodplain Management Section. Application procedures and construction standards are similar to those described for Yellowstone County.

Additional state environmental regulations applicable to an MHD retrofit of an existing power plant not already discussed were not identified.

3.5.3 Federal Regulations

Other federal environmental regulations applicable to MHD retrofits, in Montana and nationally, include:

- Fish and Wildlife Coordination Act, 16 U.S.C. 661, et. seq. This act requires federal agencies to coordinate their impact analysis of projects with the U.S. Fish and Wildlife Service under certain circumstances;
- Executive Order 11988, Floodplain Management, May 24, 1977. This order addresses developments on floodplains; and

- Executive Order 11990, Protection of Wetlands, May 24, 1977. This order addresses developments in wetlands.

If the MHD retrofit will be federally owned then some additional federal rules will apply:

- Executive Order 12088, Federal Compliance with Pollution Control Standards, October 13, 1978;
- OMB Circular A-106, Reporting Requirements in Connection with the Prevention, Control, and Abatement of Environmental Pollution at Existing Federal Facilities, December 31, 1974;
- EPA, Procedures for Reporting Proposed Pollution Abatement Projects for Federal Facilities, January 9, 1975;
- DOE Order 5480.1A Environmental Protection, Safety and Health Protection Program for DOE Operations, August 13, 1981;
- DOE Order 5482.1 Environmental Safety, and Health Appraisal Program, June 21, 1979;
- DOE Order 5484.1 Environmental Protection, Safety, and Health Protection Information Reporting Requirements, February 24, 1981; and
- DOE Order 5484.2, Unusual Occurrence Reporting System, August 13, 1981.

3.6 Health and Safety

The Occupational Safety and Health Act (29 U.S.C. 688 et. seq.) established workplace practices to protect the health and safety of workers. Enforcement

is by Occupational Safety and Health Administration (OSHA) inspections of workplaces and issuance of compliance orders, rather than by permit system.

State and Federal Government agencies are not subject to the inspection and enforcement provisions of the Act. Federal agencies are responsible for worker safety, therefore are required to develop employee health and safety programs, and must comply with OSHA standards. If the MHD retrofit facility is a government project then the inspection and enforcement provisions of the Act do not apply. However, DOE would be responsible for ensuring that all applicable OSHA standards are met. If the project is privately owned, then all OSHA regulation, including inspection and enforcement responsibilities would apply.

3.6.1 Construction

Worker health and safety during construction would be covered by the OSHA Construction Standards. These standards are common in the construction industry. An MHD retrofit would not present any new hazards during construction phase.

3.6.2 Operation

OSHA regulations applicable to steam generation facilities will probably apply to the thermal and coal-handling plant. These OSHA regulations establish workplace exposure limits and guidelines for non-ionizing radiation, hazardous materials (including compressed gases and flammable liquids), and toxic and hazardous emissions (including arsenic, benzene, and

several other organic compounds which may result from coal combustion). Also regulated are noise and fire hazards.

The exact nature of all workplace hazards for MHD is not yet known. As the development of an industrial health and safety program for MHD technology progresses, applicable standards will be established. Major new areas of concern for MHD plants include:

- Hazards associated with superconducting magnets;
- Hazards associated with finely ground coal; and
- The oxygen plant.

The oxygen plant associated with an MHD retrofit has hazards not found in the usual steam generator plant. However, OSHA standards have been set that are applicable to operation of an oxygen plant and the MHD retrofit oxygen plant will have to meet these standards.

3.7 Summary of Environmental Requirements

Environmental requirements that are unique to the MHD retrofit of the Corette plant in Billings, Montana are summarized in subsequent paragraphs.

3.7.1 Siting Requirements/NEPA-MEPA

If DOE owns the retrofit, the substantive requirements of the Montana Major Facilities Siting Act will have to be addressed. If the retrofit is privately owned, the substantive and procedural requirements of the Act will have to be addressed.

3.7.2 Air Quality

The design of the retrofit must ensure that New Source Performance Standards (NSPS) for all air emissions will be met. In addition, if Billings is given non-attainment status for SO_2 then the retrofit must control all SO_2 emissions.

3.7.3 Water Quality

Water requirements and waste water disposal will be constrained by environmental regulations. If the retrofit plus the Corette plant will use more than 92,800 acre feet per year or more than 57,550 gallons per minute (the current MPC appropriation for the Corette plant) then an additional appropriation of water will be needed. The current appropriation is for once-through cooling and screen cleaning; thus, it is a non-consumptive use. The MHD retrofit use of this water will also have to be non-consumptive.

Water discharge to the Yellowstone from the retrofit will require an MPDES permit. Current limitations on Corette cooling water discharge indicate that the MHD retrofit will probably not be allowed to discharge waters that would cause an increase in the existing allowable total thermal load from the Corette and Bird plants. This limitation must be taken into account during the final design stage.

3.7.4 Solid Waste

Major considerations that will need to be addressed during final design of the retrofit include solid waste disposal regulations. First, all wastes will need to be identified as hazardous or nonhazardous. Hazardous wastes (if any) will have to be disposed in an EPA or DHES approved manner. Nonhazardous wastes will also have to be disposed in a manner approved by DHES. As no room exists on site for disposal of solid wastes from the MHD retrofit off-site facilities will have to be found. As the county Class II landfill could refuse to handle the nonhazardous wastes a plan for disposal of 4.5 tons/hr of slag, and 5 tons/hr spent seed produced during operation will have be be finalized.

3.7.5 Safety and Health

Safety and Health aspects of the coal handling, oxygen plant, and magnet should be addressed during the final design stage to ensure worker protection. These aspects may be somewhat different than those found for a conventional coal-fired power plant.

4.0 SOCIOECONOMIC CONSIDERATIONS

Retrofit of an existing power plant with an MHD topping cycle will require that applicable socioeconomic regulations and their appropriate socioeconomic requirements be followed. Depending on local and state regulations and the ownership of the MHD system (federal or private) certain siting, historical, archaeological and zoning regulations will have to be met. As discussed in Section 3.0, Environmental Requirements, this Section will also consider three MHD retrofit scenarios:

- MHD retrofit of the MPC Corette Plant, Billings, Montana; DOE ownership of new hardware;
- MHD retrofit of any coal-fired power plant in Montana; private ownership of new hardware; and
- MHD retrofit of a coal-fired power plant anywhere in the country; private ownership of new hardware.

The Montana Major Facilities Siting Act (MMFSA), The Montana Environmental Policy Act (MEPA), and the National Environmental Policy Act (NEPA) were discussed (with relationship to the three ownership scenarios) in Section 3.1 Site Requirements/NEPA-MEPA and depicted in Figures 3-1 and 3-2. To avoid repetition this section will not discuss MMFSA, MEPA, or NEPA requirements with respect to ownership, but will limit to discussion to specific socioeconomic requirements of the three when they do apply.

4.1 MMFSA, MEPA, NEPA

As previously discussed in Section 3.1.1, the MMFSA will apply to a private and/or federally owned retrofit of the Corette Plant in Billings or to any other MHD retrofit in Montana. Socioeconomic considerations required by an applicant for the MMFSA include:

- Developing an inventory of public service facilities and determining their adequacy based on generalized standards of acceptable service. Examples of facilities include water supply, waste water treatment, housing, educational/recreational facilities, health care, police, and fire protection, etc.
- Determine the economic impact on the area based upon the magnitude and speed of population change and the ability of the area to accommodate those changes. Good information on the construction crew and scheduling is necessary to determine the impacts. Once the population changes have been estimated the increases in housing and public facilities can be evaluated and thus a quantitative evaluation can be made.
- Develop a social baseline or community profile based on population profile and utilization and capacity of social services including health and welfare.
- Perform an attitudinal survey of randomly selected people in the impacted area. The survey should address people's attitudes and perceptions about growth, community services, and the proposed development.

- In addition to the community survey, key agencies and organizations affected by the proposed facility should be contacted.
- Describe the visual impacts on the regional topography and physical background characteristics of the site.

NEPA and MEPA applicability was discussed in Section 3.1.1 and 3.1.2 with respect to facility ownership and general Environmental Impact Statements (EIS)/Environmental Assessment (EA) requirements. These two laws are virtually identical in their statements of policy and directions to administrative agencies. State and federal EIS procedures are similar in overall approach although they differ in detail. Federal regulations vary from agency to agency. All state agencies with EIS responsibilities have adopted uniform regulations. With respect to the broad guidelines the applicable socioeconomic factors that must be considered in the draft EIS include immediate and cumulative impacts on the human population in the area to be affected by the proposed action including where appropriate:

- Social structures and mores.
- Cultural uniqueness and diversity.
- Access to quality recreational and wilderness activities.
- Local and state tax base and tax revenues.
- Agricultural and industrial production.
- Human health.
- Quantity and distribution of community and personal income.
- Transportation networks and traffic flows.
- Quantity and distribution of employment.

- Distribution and density of population and housing.
- Demands for government services.
- Industrial and commercial activity.
- Locally adopted environmental plans and goals.

The discussion should take into consideration different scenarios and how they will impact the specific areas including:

- Status quo.
- Proposed development.
- Cumulative impact with more than one development.

4.2 Montana Antiquities Act Permit

4.2.1 Federal Ownership

For any project occurring on federally-controlled lands or which requires federal permits (beyond those related to air and water quality), compliance with the provisions of 36 CFR 800 will be necessary. There is no formal connection between the federal statute (i.e., the National Historic Preservation Act, PL.89-665) and the State Antiquities Act (i.e., 22-3-401 through 442, MCA). As the project will occur on privately-owned (MPC) land, and as the 36 CFR 800 procedures will be triggered only if particular federal permits are required, compliance with the Montana statute is not strictly applicable to the Corette MHD retrofit project. However, as the MMFSA does refer to consideration of cultural resources during the siting process, the spirit of the Antiquities Act should be addressed. This recommendation is discussed in the following subsection.

4.2.2 Private Ownership

The Montana Antiquities Act is triggered solely by projects that will use or disturb Montana state-owned lands. However, it is likely that administrative regulations pertaining to consideration of cultural resources, under the authority of the MMFSA, will be promulgated within a year from now. Such regulations will be similar in content to those found in 36 CFR 800. (Ms. Marcella Sherfy, phone conversation, April 28, 1983.)

The requirements for the determination of cultural resources in the MMFSA are very general. Therefore, the Montana DNRC has followed the federal regulations (36 CFR 800 *et seq.*). The major requirements for the applicant include:

- Evaluation of the historic value of the existing facility.
- Provide information on the land to be disturbed to determine if an inventory will be needed.

4.2.3 Situations Involving Montana State-Owned Lands

The MHD retrofit scenarios include the case of "any coal-fired power plant in Montana" (p. 4-1). In such a general use, the possibility of disturbance of state-owned lands exist. In such an instance, the State Historic Preservation Office (SHPO) personnel would administer the requirements of the Montana Antiquities Act. The applicable requirements include:

- Legal location of project;

- File search to identify previously located historic and archaeological resources;
- Written documentation that SHPO has been contacted and provided with known archaeological or historical sites and information on the likelihood of discovering cultural resources within a project area;
- Provide to SHPO a recommendation on whether an intensive cultural survey is needed;
- If a survey is needed, the applicant must supply a written report including maps, photographs, summary evaluation;
- Mitigation plans or avoidance options for register eligible or state heritage properties; and
- If a federal project, documentation of contact with the Advisory Council on Historic Preservation is required.

There is no statutory timeframe for review and approval or denial of this permit, however once granted, the permit is valid for the lifetime of the project.

4.3 Land Use and Zoning Requirements

4.3.1 Private Ownership

If the facility is located within the limits of a municipality it will be subject to zoning regulations. County zoning in unincorporated areas also exist in some places and where it does not, special zoning districts have been established in many locations.

If subject to zoning regulations, the applicant must submit an application for a building permit for the specific site of construction. The city, county, or city-county planning office will then make a determination whether the application is valid and issue or deny a permit. If the permit is denied, the applicant may request an exception be made to the zoning regulations. Again, the permit may be granted or denied by the zoning board. All decisions may be appealed to the district court within 30 days. With respect to the Corette Plant in Billings, it appears that the facility and retrofit is within an area zoned industrial, therefore the permit should be easily obtained.

4.3.2 Federal Ownership

Zoning regulations do not apply to facilities under the exclusive jurisdiction of an agency of the federal government. However, it may be beneficial to the federal government to voluntarily comply with the zoning regulations.

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9. "Characteristics of Seed-Slag Fouling in MHD Steam Plants", by L. S. H. Chow, P. F. Dunn, T. R. Johnson, C. B. Reed and B. J. Schlenger, Argonne National Laboratory, published in the Proceedings of the 20th Symposium on the Engineering Aspects of Magnetohydrodynamics, Irvine, California, June 14-16, 1982.

10. "New Features and Applications of PRESTO, a Computer Code for the Performance of Regenerative, Superheated Steam Turbine Cycles, "by Y. K. Choo and P. J. Staier, NASA Technical Paper 1954, Lewis Research Center, Cleveland, Ohio, 1982.

11. "APBAL: All Purpose, Non-Iterative, Energy and Loss Balance Program", by C. P. Ashworth and R. E. Price, Pacific Gas & Electric Company, San Francisco, CA., September 25, 1981; attachment to a private communication from S. C. Goschke of PG&E to M. Miller of MSE, June 17, 1982.

12. "PEPSI (TM) Manual, Volume I, User Input Description", by W. C. Kettenacker, P. H. Klink, G. L. Minner, Energy Incorporated, Idaho Falls, ID, last revision May 1, 1982.

13. "CDIF Enhancement Study", Volume I - Technical Report, prepared by the Montana Energy and MHD Research and Development Institute, Inc., February 16, 1980.

14. "Magnetohydrodynamics (MHD) Engineerng Test Facility (ETF) 200 MW_e Power Plant", Conceptual Design Engineering Report (CDER), Volume I - Executive Summary, prepared by Gilbert/Commonwealth, prepared for NASA Lewis Research Center, September 1981.
Document Nos: DOE/NANA/0224-1, NASA CR-165452

15. Magnetohydrodynamics (MHD) Engineering Test Facility (ETF) 200 MW_e Power Plant", Design Requirements Document (DRD), prepared by H.S. Rigo, et.al., NASA Lewis Research Center and A.M. Hatch Massachusetts Institute of Technology, prepared for U.S. Department of Energy, September 1981. Document Nos. DOE/NASA/ 10769-20, NASA TM-82705.

16. "A Preliminary Analysis of MHD Retrofit for the Colstrip Power Plant", prepared for the U.S. Department of Energy Division of Magnetohydrodynamics, Contract No. ET-78-C-01-2688, prepared by Gilbert/Commonwealth, June, 1980. Document No. 2152.

17. Personal Communication with Ralph Ferraro, Electric Power Research Institute, Palo Alto, CA., March 3, 1983.

18. Personal Communication with Emerson Ray, Westinghouse, Elec. Corp., Pittsburgh, PA, March 1, 1983.

19. Personal communication with Kent Koester, Stanford Research Institute, Berkley, CA, February, 1983.

20. "RCRA Leachate Analysis of Slag From Magnetohydrodynamic (MHD) Coal Combustion", Michael D. Dahlberg, Environmental Science and Technology, Vol. 17, No. 3, March 1983.

21. "Federal, State and Local Government Permit Requirements for Resource and Energy Development in the State of Montana", Kay Harrison, Governor's Office, State of Montana, Helena, Montana, November 1982.

ATTACHMENT #2

Project Revision Comments

MONTANA
POWER
COMPANY
mpc
GENERAL OFFICES: 40 EAST BROADWAY, BUTTE, MONTANA 59701 • TELEPHONE 406/723-5421

May 2, 1983

Mr. E.W. Ashby
Mountain States Energy Inc.,
P.O. Box 3662
Butte, MT 59701

RE : Review of Phase II
Design Requirements

Dear Gene:

The Montana Power Company is in agreement with the basic design requirements in your document "MHD Retrofit, J.E. Corette Plant, Configuration Analysis and Design Requirements". Specific areas requiring further analysis has been identified at our working meetings. These are not in conflict with the basic concepts presented, but areas requiring a more detailed evaluation towards improved operability.

Very truly yours,

Fred E. Walter

Fred E. Walter
Senior Engineer
MPC

FEW/sv/A:2

PP&L Pennsylvania Power & Light Company
Two North Ninth Street • Allentown, PA 18101 • 215 / 770-5151

April 20, 1983

Mr. E. W. Ashby
Mountain States Energy Inc.
P. O. Box 3662
Butte, Montana 59702

Dear Mr. Ashby:

The report is very well done and I don't have any comments. I feel that the parameters such as oxygen enrichment vs. air preheat have been well chosen. The size, with the constraints imposed by the operating needs of the Montana Power Company, is reasonable.

What else is necessary, even though it is not part of the design study, is a definition of the key experimental and developmental work that is needed for the continuing D.O.E. efforts to remove some of the remaining uncertainties in the design. This would be a valuable plan for the federal program.

I continue to have a close interest in the program and would like to continue to be kept informed.

Very truly yours,

Heinz G. Pfeiffer

DUKE POWER COMPANY
GENERAL OFFICES
422 SOUTH CHURCH STREET
CHARLOTTE, N. C. 28242

P. O. BOX 33189

TELEPHONE: AREA 704
373-4011

April 27, 1983

Mr. E. W. Ashby
Mountain States Energy, Inc.
P. O. Box 3662
Butte, Montana 59702

Subject: Magnetohydrodynamic Retrofit Plant
Engineering Assessment (Draft)
Comments On

Dear Mr. Ashby:

We have reviewed your draft document entitled "MHD Retrofit - J. E. Corette Plant," and have no comments on the engineering assessment aspects of the proposed design. We note one technical issue which we believe should receive further attention as detailed design progresses.

It has been proposed that the monitoring and control of the MHD portion of the plant be through use of distributed microprocessors and multiplexed information channels to a central computer control system. We are not certain that the environmental conditions in this unit will be compatible with extensive use of electronic signals. We note that the problem of magnetic shielding and isolation will be very difficult as increases are made in size and strength of the magnet. Since extensive use of non-ferrous structural materials will probably be too costly, there will most likely be a number of stray magnetic fields induced in all areas of the plant which will tend to interfere with the ability of microprocessor controls to operate reliably. We also note that there may be strong radio frequency fields generated in the inverters which will tend to interfere with sophisticated control. Experience in the power industry in general has not been particularly good with sophisticated electronic controls. We recommend that a less susceptible system be selected for monitoring and control wherever possible, such as pneumatics, or that the control system specification require particular attention to the possibility of magnetic or rf interference with appropriate testing to verify adequate performance.

If you have any questions, please call me at 704-373-6215.

Very truly yours,

S. K. Blackley, Jr., Chief Engineer
Mechanical & Nuclear Division

A. L. Sudduth

A. L. Sudduth, Design Engineer II

ALS/kh

cc: C. L. Sansbury, R. E. Miller, R. C. Day (SRAL)

SERVING NEBRASKA

THE CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT

See reverse for complete addresses and telephone numbers

April 28, 1983

Mr. W. W. Ashby
Mountain States Energy, Inc.
P.O. Box 3662
Butte, Montana 59702

Dear Mr. Ashby:

I found the "MHD Retrofit J. E. Corette Plant Configuration Analysis and Design Requirements" very interesting. I was a little surprised at the small MHD output as compared to the HRSR. I was not aware of this ratio previously. I have no other comments.

Sorry this is a little late.

Sincerely,

E L Hamilton

E. L. Hamilton
Chief Electrical Engineer

sm

Consumers
Power
Company

Robert E. Albrecht
Director of Facilities Planning

Room CP-CAI-4C-14
General Offices: 212 West Michigan Avenue, Jackson, Michigan 49201 • (517) 788-2200

April 29, 1983

REA-22-83

Mr E W Ashby
Mountain States Energy Inc
P O Box 3662
Butte, Montana 59702

REFERENCE: 83MSE-50

SUBJECT: Engineering Assessment of an MHD Retrofit to an Existing Utility Steam-Electric Generating Station

Dear Mr Ashby:

We have reviewed the preliminary draft of "MHD Retrofit, J E Corette Plant, Configuration Analysis and Design Requirements" and have no substantial comments to make at this time.

Sincerely,

R E Albrecht /am

REAlbrecht/am

Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

April 25, 1983

Mr. E. W. Ashby
Mountain States Energy
P. O. Box 3662
Butte, Montana 59702

Dear Mr. Ashby:

Subject: Engineering Assessment of an MHD Retrofit

As requested in your letter of April 8, 1983, I have reviewed and made margin comments on the draft MHD retrofit engineering assessment report.

I must say, however, that I continue to doubt the operability of parallel steam paths without individual control valves. I also have reservations about the desirability or feasibility of adding an overall supervisory control system. This seems like an unnecessary complication.

If you have any questions, please give me a call at (213) 572-1888 as I would like to discuss my comments with you.

Sincerely yours,

Jim Griswold

J. W. Griswold

Enclosure

cc: J. D. Leeper

Vepco

VIRGINIA ELECTRIC AND POWER COMPANY

April 20, 1983

Mr. E. W. Ashby
Mountain States Energy Inc.
P.O. Box 3662
Butte, Montana 59702

Dear Mr. Ashby:

ENGINEERING ASSESSMENT OF AN MHD RETROFIT

Thank you for extending the opportunity to review the MHD Retrofit document forwarded by your letter of April 8, 1983. Our engineering resource availability and prior committments necessitates advising you that Vepco will be unable to provide the requested reviews.

Perhaps assistance may be available at a future date.

Very truly yours,

W. C. Spencer
Vice President
Power Station Engineering

Allegheny Power System

Bulk Power Supply
Cabin Hill, Greensburg, PA 15601 (412) 838-6539

HOMER T. McCARTHY
Director, Generation Planning

April 21, 1983

Mr. E. W. Ashby
Mountain States Energy Inc.
P. O. Box 3662
Butte, MT 59702

Dear Mr. Ashby:

Engineering Assessment of an MHD Retrofit to an Existing Utility
Steam-Electric Generating Station

I appreciate receiving a draft copy of the configuration analysis and design requirements for your MHD retrofit project.

We have no comments to offer on this draft, but would like to be kept informed of significant developments.

Very truly yours,

H. T. McCarthy

Illinois Power Company

500 SOUTH 27TH STREET, P. O. BOX 511, DECATUR, ILLINOIS 62525-1805

April 26, 1983

Mr. E. W. Ashby
Mountain States Energy Inc.
Post Office Box 3662
Butte, Montana 59702

Dear Mr. Ashby:

We have reviewed the report entitled, "MHD Retrofit, J. E. Corette Plant, Configuration Analysis and Design Requirements" that accompanied your April 8, 1983 letter. We are in agreement with the engineering approach outlined in the report. However, we have found some syntactical errors which are listed in the attached.

We appreciate being kept informed of the progress being made in the MHD efforts and look forward to hearing from you in the future.

Sincerely,

R. D. Reynolds

R. D. Reynolds
Research Section

RDR/djt10

cc: Mr. H. J. Rand, C-21

Attachment

Table of Contents

2.1.3. Resultsc should be: Results

Page 4

1. Achieve the same or great overall plant -- should be: same or greater ---.

Page 11

The primary thermodynamic properties of interest are the specific heat (CP, should be: (CP)

Page 37

The inability to simulate a plit should be: Split

Page 2-20 Figure 2.1.6-1

SFC Circuit Breaker should be: SF6 Circuit Breaker

AVCO EVERETT RESEARCH LABORATORY, INC.

A SUBSIDIARY OF AVCO CORPORATION

2385 REVERE BEACH PARKWAY
EVERETT, MASSACHUSETTS 02149
TELEPHONE: 617 389-3000

April 15, 1983

Mr. E. W. Ashby
Mountain States Energy, Inc.
P. O. Box 3662
Butte, MT 59702

Dear Mr. Ashby:

This letter is in response to your letter of April 8 with enclosed draft copy of your Milestone 3 report entitled, "MHD Retrofit J. E. Corette Plant, Configuration Analysis and Design Requirements."

I have reviewed your report and offer the following comments.

I am pleased to see that the required enthalpy extraction now is lowered and stipulated to be 10% plus. This can readily be reached for a thermal input with the coal fuel of 250 MW which your channel calculations also show (12%). I assume that the indicated capacity and power extraction of the ATS have met with the approval of the utilities presently involved (MPC., etc.) and considered by them as adequate for proof testing of commercial MHD power generation. Personally, I feel it is important to get EPRI's early response to the overall retrofit concept and ATS size, because I believe that EPRI sooner or later will play an important role in the financing and undertaking of this program.

Regarding the MHD channel design itself, net MHD power (gross MHD power minus cycle compressor power and oxygen plant compressor power) generated (Fig. 4 on p. 31) is more important than gross MHD power (Figs. 1, 2, 3 and 5 on pages 28, 29, 30 and 31). I definitely agree with the selection of supersonic channel operation (Mach No. ~ 1.2) at a more moderate peak magnetic field strength of 4.5 as appropriate for this retrofit program. Our APT channel performance calculations have shown this also to be preferable for early commercial MHD/Steam power plants both of 200 MW and 500 MW total electrical outputs. It offers substantial cost savings and less risks for the magnet compared to subsonic channel operation at peak field of 6 Tesla and the penalty in performance is small. Further optimization and details of the supersonic channel design for this Retrofit program, I assume will be done later. From our own preliminary channel calculations, I have concluded that a gross enthalpy extraction of 12-13% can be reached for the selected design conditions with a coal thermal input of 250 MW and supersonic operation at 4.5 Tesla peak field. The electrical stresses and gasdynamic and thermal operating conditions of the channel can be made reasonable and within the range where experience with long duration channel operation already has been gained (MK VI). However, there are certain design assumptions and parameters that you have selected for the ATS that I recommend you change or review further. These will now be discussed.

First and most important, the coolant temperature for the channel should not exceed 260°F to be within the present state of the art in channel technology.

Second - I note that you have based your combustor design on 85% ash rejection or 15% ash carryover with the MHD combustion gases to the channel. This is in our experience marginal to ensure continuous slagging of the channel walls. Experimentally, we have obtained proper slagging of our channel walls with 20-40% ash carryover based on 10% ash content of the coal and a higher degree of oxidizer oxygen enrichment than here considered. Because of this and also to lessen the design requirement for ash rejection of the combustor, I recommend an ash carryover from the combustor of 30-40% in these design analyses. Furthermore, the air/fuel equivalence ratio of the MHD combustion gases generated in the combustor is specified as 0.95. This stoichiometric ratio is too high to ensure NO_x emission control. Therefore, I recommend that the air/fuel equivalence ratio be lowered to 0.85-0.90. The performance of the MHD generator will most likely increase slightly because of the higher gas conductivities obtained for this lower stoichiometric ratio. Electrical isolation of the slag removal system from the combustor is an important item which should be addressed in addition to the electrical isolation of the reactant feed lines and coolant system.

Third - The channel design is based on an oxygen enrichment of the oxidizer of 36% by volume. This degree of oxygen enrichment has been arrived at under the assumption of a new process for production of oxygen. This new process utilizes internal compression and liquid product pumping which reduces the specific energy consumption (SEC) to 175 kWhr/ton equivalent pure oxygen. However, this process is not present stage of the art which I recommend for this program (unless you can obtain satisfactory guaranty from Lotopro Co., or any other oxygen plant supplier for this new process). An optimized conventional oxygen plant will have a SEC of 195 kWhr/ton equivalent pure oxygen which I recommend to use for this study. This will lower the optimum degree of oxygen enrichment of the oxidizer, which is determined mainly by trade-off analyses between cost of the oxygen plant (size) and MHD power train performance. (Note that maximum MHD power is not equivalent to optimum overall system design conditions.) In any event, I recommend a certain margin in the oxygen plant capacity as reserve and safeguard against present uncertainties in burner performance.

Fourth - The exit pressure from the diffuser has been assumed to be 1.2 atmosphere and its pressure recovery factor 0.45. According to my experience, boiler manufacturers like to have balanced pressure in the primary radiant furnace and no overpressure to avoid any possible leakage of gas out of the furnace and maintenance problems. According to this, the diffuser exit pressure should be lowered to 1.00 atm. and an induced draft fan(s) is required. The selection of the pressure recovery factor of 0.45 is considered quite conservative. A higher value of 0.6 is realistic based on limited measurements of MHD diffuser efficiency in connection with experimental MHD generator testing (MK VI).

Fifth - Electric motor drives are specified both for the cycle compressor and O_2 plant compressors. Information developed in previous studies (ETF, etc.) has indicated that electric drives become relatively costly compared to steam turbine drives where compressor controls and efficient part load operation is desired. Therefore, I recommend to perform trade-off analyses between steam turbines and electric motor for drives of the compressors (maybe also gas fired gas turbines

should be included in these trade-off analyses). This must include the steam source and necessary condensing equipment in case of steam turbine drives. An auxiliary boiler (gas fired) would probably be necessary if the existing steam generator cannot provide steam for startup and initial operation until the bottoming plant steam generator can generate sufficient steam for compressor operation.

Sixth - The combined operation of the ATS with the existing unit including parallel boiler operation represents a control problem which must be addressed in more detail to determine its practicality. This should include initial check-out, testing, start-up, full and part load operation, load following, emergencies, shut-down, etc. Certainly, all of the control problems cannot be solved in this initial design phase, but a sound and practical overall design philosophy for testing, controls and operation should be sought. Individual first checkout and testing of the MHD coal combustor and power train is recommended. This would require facilities for quenching and by-passing of the MHD generator exhaust gas directly to the stack and environmental variance for this separate testing.

An auxiliary condenser should be considered for direct dumping of steam from the HRSR unit for initial checkout and possibly also for practical parallel boiler operation (start-up, emergencies, etc.). This auxiliary condenser and the condenser equipment required in case of auxiliary steam turbine drives of the compressors could possibly be combined as one auxiliary condenser unit.

Seventh - One spare channel should always be at hand to provide for rapid channel maintenance and return to service. Close coordination between the channel and magnet designer is a must to arrive at a practical magnet design and optimum costs.

Eighth - It is not clear to me why auxiliary coal burners are required for coal drying. The use of relatively low grade heat of the combustion gases either directly or indirectly (N_2 heating) appears to be thermodynamically the most attractive.

Ninth - Your report status that supersonic MHD channel efficiency drops off quickly for off-design conditions (p. 34). My own part load analyses have shown that both supersonic channel operation and subsonic channel operation can maintain a relatively high efficiency at least down to 70% load and probably lower, so I find your statement regarding part load supersonic channel efficiency misleading.

My time for reviewing your report draft has been limited, but I hope the above comments are useful to you. Please advise if you require more information at this time.

Sincerely,

F. A. Hals
Principal Research Engineer

Stewart Way
April 25, 1983
(Milestone 4)

COMMENTS ON REPORT

MHD RETROFIT
J.E.CORETTE PLANT
CONFIGURATION ANALYSIS
AND
DESIGN REQUIREMENTS

Mountain States Energy Company

1. General comment: This is a thorough report and gives broad and good coverage of the proposed retrofit plant analysis and design requirements.
2. The compressor power (compressor + ASU) is 55% of the gross MHD power. In a well designed system, or in a practical MHD/ steam plant, it should be only 25 to 30%.
3. No allowance in the power tabulation is made, apparently, for the MHD auxilliaries. This might be about 5 MW.
4. Some data and figures are not mentioned, including combustor top temperature, gas states and conductivity values in the MHD channel, and generator heat loss.
5. With a changed design approach it should be possible to realize a much higher enthalpy extraction than the 12% cited. It is somewhat disheartening to see a major MHD project of this type focussing on such low goals.
6. The curve of Figure 1 is not discussed in the text. (The writer could not find such discussion). This curve is really irrelevant for two reasons, (a) it does not consider compressor power along with the MHD power, (b)for given inlet conditions best enthalpy conversion generally goes with a load current somewhat less than the so called optimum. The generator coefficient should generally be 0.7 to 0.8 . There is a trade off between generator length and enthalpy extraction, in general.
7. Since a practical MHD power plant would probably have a subsonic generator and low oxygen enrichment it would seem appropriate to follow the same course in the ATC.
8. In the curves of Fig. 2 and Fig.3 no abscissa scale is shown. These curves are difficult to interpret.
9. In the comparison of subsonic and supersonic generators, was the better diffuser pressure recovery for the subsonic case considered?
10. In the subsonic generator more favorable results would have been obtained if a falling velocity through the channel had been used.
11. One TABLE of Contents rather than two would have been preferable .
12. Have thermodynamic checks been made of the cooling requirements (combustor, channel, diffuser, inverter, etc) in comparison to the heat absorbing capability of the MHD portion of the feed water?
13. The figure 5500 gpm water flow for bearing cooling seems unreal. Is this correct?
14. The feed water flow routing in Fig. 2.3.2-1 does not agree with that in the Drawing DO2-DNRC-001 .
15. What type of compressors are proposed? Axial, centrifugal, reciprocating?
16. Some would not agree that design and control are more uncertain in subsonic than supersonic channels.
17. At the top of page 17 one finds the words " by role ". Is this a typo error?

18. On page 2-68 reference is made to converting "unspent" K_2CO_3 to K_2SO_4 . Formation of K_2SO_4 is limited by the amount of SO_2 present in the gas. The real object is to capture as much of the sulfur as possible. In a low sulfur coal like the Montana sub-bituminous there will be some carbonate and probably some hydroxide or nitrate left over after most of the sulfur has been combined to sulfate.

19. Attachment of reviewers comments and replies was mentioned. These attachments could not be found.

ATTACHMENT #3

Comment Responses

ATTACHMENT #3

RESPONSE TO REVIEWER'S COMMENTS

The following remarks address some of the more important comments and questions that were received from reviewers.

1. QUESTION: Why is it necessary to predry the coal to 5% before injecting it into the MHD coal combustor?

   RESPONSE: Montana Rosebud coal typically contains 23 1/2 - 24% moisture on average. Injection of this much water would severely depress the flame temperature and hence the plasma conductivity. Detailed calculations using chemical equilibrium codes show that if the coal is dried to 5% moisture content, the combustor flame temperature will be approximately 2800°K, which is an acceptable value.

2. COMMENT: The feedwater heating path from the feedwater heater train through the MHD power train may not perform as designed.

   RESPONSE: This is a problem which was identified some time ago. The basic problem here is that the feedwater temperature of 460°F at the originally proposed tie-in point (downstream of heater number 5) is too high. Presently, state-of-the-art channel design imposed a maximum cooling water temperature of 260°-270°F, through the channel walls. Several options are being studied, but it is clear that the feedwater

extraction point will be moved upstream, closer to the condenser. The extraction point shown in the Milestone 4 document (upstream of the boiler feedwater pump) is perhaps a slight, improvement, but the temperature at that point may still be unacceptably high. It is probable that one or more of the feedwater heaters will have to be bypassed and the extraction steam shut off during combined cycle operation. This would have a beneficial effect on the turbine-generator output, but until a much more detailed analysis of this problem has been done, and additional discussions with the host utility have taken place, no further changes in the feedwater heating path will be recommended.

3. COMMENT: The air/fuel equivalence ratio is too high to ensure NO_x emission control

   RESPONSE: The proper stoichiometric equivalence ratio for acceptable NO_x control is still the subject of continuing investigation. This question can only be resolved experimentally. On-going work at Argonne Laboratory and UTSI should give some definitive answers in the near future.

4. COMMENT: The ash rejection value of 85% specified in the design may be too high to permit adequate slagging of the channel walls.

   RESPONSE: This may or may not be true. Since slagging is a surface deposition process, the required amount of slag flow per unit time that would be necessary to achieve complete wall coverage should be

proportional to the total wall area, whereas the required combustor mass flowrate will be proportional to channel volume. Therefore as a given channel design is scaled up the required amount of ash rejection may not be a fixed fraction of the combustor mass flow. Additional experimental work will be required to resolve this question.

5. COMMENT: Steam turbine drives rather than electric drives may be preferable for driving the oxidant compressor and the O_2 plant compressor, because they will probably be less expensive and also should be easier to control.

RESPONSE: The point is well taken. This question probably cannot be resolved in the present study. The primary advantage of electric drives is that they make plant start-up somewhat easier, and this was the reason for specifying them originally. A third point in favor of steam drives is that they could be driven from extraction steam from the turbine which might be available as a result, of bypassing one or more of the feedwater heaters. This suggestion has considerable merit and will be considered as an option in the final report.

ATTACHMENT #4

Corette Plant Trip Report

MULTITECH, INC.
TECHNOLOGY SERVICES
POST OFFICE BOX 4078
BUTTE, MONTANA 59701
(406) 494-6319
FTS 587-6319

Date: May 4, 1983

To: Gene Ashby

Thru: Neal Egan NE

Copies:

From: Allan Miller; John Cromer JC

Subject: Trip Report: MPC Corette Plant, April 28, 1983

A visit was made to the Corette Plant to confirm interface connections with MHD systems, confirm layout arrangements, assess requirements of existing equipment or buildings that would require relocation, and generally review portions of the Milestone 4 report with plant personnel. Mike Hofacker (MPC senior engineer) assisted us in the plant tour and analysis of systems.

We discussed an operational description of the MHD process with plant personnel, Paul Ratte - Assistant Superintendent, Joe Stirling - Results Engineer, and Jim Erickson - Assistant Maintenance Superintendent. This interface proved to be valuable as it provided some indoctrination of the MHD process to those individuals and also provided us with valuable feedback on the plant that can be incorporated into the Milestone 5 report.

Of particular interest was the confirmation of items that would require relocation or removal during ATS construction. That investigation will result in some modifications to the Milestone 5 report to more accurately reflect plant site conditions. The following major items were investigated: 100 kV transmission line routing; No. 5 coal conveyor support structures; No. 5 coal conveyor interface locations; service water supply at intake structure; synchronous condenser location; 50 kV transmission line locations; yard drainage; construction rail spur; condensate tank interface; condensate makeup to turbine condenser; 10" bottom ash line relocation; and control room requirements.

The plant visit was successful in identifying some major problem areas and will allow us to correct deficiencies for the Milestone 5 report and provided information on areas requiring further study and analysis during the preliminary design phase of the ATS.

ADM/JWC/rd

ATTACHMENT #5

Project Review Meeting Invitation

Mountain States Energy Inc.
POST OFFICE BOX 3662
BUTTE, MONTANA 59702

83MSE-053

April 29, 1983

Subject: MHD Advanced Test-System Retrofit: Engineering Assessment Review Meeting.

Dear

Thank you for your interest and participation during the development of the subject Engineering Assessment.

A final technical review of the completed Engineering Assessment will be conducted at a meeting in Butte, Montana on June 1, 1983 and you are cordially invited to attend this review to be held in the offices of Mountain States Energy, Inc.

Since your interest in the MHD Technology Development is especially valued, it is hoped your schedular commitments will permit your attendance at this meeting. I would appreciate knowing by Friday, May 20, 1983 whether or not you can attend.

If you have any questions concerning this review meeting, please let me know.

Sincerely,

E. W. Ashby
Mountain States Energy, Inc.

EWA/dlk

Attachment: Agenda

Dr. Manoj Guha
Staff Scientist
Advanced Energy Research Group
American Electric Power
Two Broadway
New York, NY 10004

D. L. (Bruce) Broussard
Vice President
Research & Development
Arizona Public Service
P.O. Box 2166
Phoenix, Arizona 85036

Harry D. Fletenstein, Jr.
President
Head Plant Engineer
Central Illinois LIght Company
300 Liberty Street
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R. E. Albrecht
Vice President
Systems Operation
Consumers Power Company
1945 West Parnell Road
Jackson, Michigan 49201

Mr. A. L. Sudduth
Duke Power Company
P.O. Box 33189
Charlotte, North Carolina 28242

Ned Spake
Vice President
Environmental and New Technology
Florida Power Corporation
3201 34th Street South
P.O. Box 1404L
St. Petersburg, Florida 33733

Mr. Dick Phodenizer
Manager, MHD Programs
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Mr. Stephen Anderson
Resource Appraisal and Fuel Conversion
Group Leader
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Mr. P. E. Schaub
Manager, New Technology Program
Potomac Electric Power Company
1900 Pennsylvania Ave. N.W.
Washington, D.C. 20068

Mr. L. D. McNair
Southern Company Services, Inc.
P.O. Box 2625
Birmingham, Alabama 35202

Mountain States Energy Inc.
POST OFFICE BOX 3662
BUTTE, MONTANA 59702

83MSE-055

April 29, 1983

Subject: MHD Advanced Test System Retrofit - Engineering Assessment Review Meeting.

Dear

A final technical review of the completed Engineering Assessment will be conducted at a meeting in Butte, Montana on June 1, 1983 and you are cordially invited to attend this review to be held at the offices of Mountain States Energy, Inc.

Reimbursement of direct transportation, meals and lodging expenses for this meeting will be made by Mountain States Energy.

Since you are considered a key participant in this project, your comments are especially valued and it is hoped your schedular commitments will permit your attendance at this meeting. I would appreciate knowing by Friday, May 20, 1983 whether or not you can attend.

We look forward to your continued participation in this project and if you have any questions concerning this review meeting, please let me know.

Sincerely,

E. W. Ashby
Mountain States Energy

EWA:dlk

Attachment: Agenda

Mr. Finn Hals
Avco-Everett Research Laboratory
2385 Revere Beach Parkway
Everett, MA 02149

Mr. Stewart Way
P.O. Box 505
Whitehall, MT. 59759

Dr. John C. Cutting
Gilbert Associates, Inc.
P.O. Box 1498
Reading, PA 19603

Dr. Richard Rosa
Department of Mechanical Engineering
Montana State University
Bozeman, MT. 59715

Dr. Donald Rudberg
Department of Electrical Engineering
Montana State University
Bozeman, MT. 59715

Dr. Roy Johnson
Department of Electrical Engineering
Montana State University
Bozeman, MT. 59715

Dr. J. N. Chapman
University of Tennessee
Space Institute
Tullahoma, TN 37388

Mountain States Energy Inc.
POST OFFICE BOX 3662
BUTTE, MONTANA 59702

83MSE-054

April 29, 1983

TO: SEE ATTACHED

Subject: MHD Advanced Test-System Retrofit: Engineering Assessment Review Meeting.

Dear

Thank you for your interest and participation during the development of the subject Engineering Assessment.

A final technical review of the completed Engineering Assessment will be conducted at a meeting in Butte, Montana on June 1, 1983 and you are cordially invited to attend this review to be held in the offices of Mountain States Energy, Inc.

Since your interest in the MHD Technology Development is especially valued, it is hoped your schedular commitments will permit your attendance at this meeting. I would appreciate knowing by Friday, May 20, 1983 whether or not you can attend.

If you have any questions concerning this review meeting, please let me know.

Sincerely,

E. W. Ashby
Mountain States Energy, Inc.

EWA/dlk

Attachment: Agenda

Fred E. Walter
Senior Engineer
Montana Power Company
40 East Broadway
Butte, MT. 59701

Mr. Don Weems
Production Engineer
Iowa Public Service Co.
P.O. Box 778
Sioux City, Iowa 51102

Mr. E. L. Hamilton
Cheif Electrical Engineer
The Central Nebraska Public Power
and Irrigation District
P.O. Box 356
Holdrege, Nebraska 68949

Mr. W. W. Kroeber
Vice President Power Supply
Montana-Dakota Utilities Co.
400 North Fourth Street
Bismark, North Dakota 58501

Mr. H. P. Lyle
Vice President, Electric Production
Northern Indiana Public Service Co.
5265 Hohman Avenue
Hammond, Indiana 46352

Mr. R. E. Buntain
Division Manager, Power Operations
Nebraska Public Power District
P.O. Box 499
Columbus, Nebraska 68601-0499

Mr. Roy J. West
Manager, Special Programs
Gulf States Utilities Company
P.O. Box 2951
Beaumont, Texas 77704

Mr. Claude W. Hiers, P.E.
Lakeland Electric and Water
1000 East Parker St.
Lakeland, Florida 33801

Mr. W. C. Smith
Senior Vice President
Savannah Electric and Power Co.
P.O. Box 968
Savannah, Georgia 31402

Mr. J. W. Griswold
Research and Development Division
Southern California Edison
P.O. Box 800
2244 Walnut Grove Avenue
Rosemead, California 91770

Mr. Thomas J. McGrath
Director, Generating Plant Engineering
Puget Sound Power & Light Company
Puget Sound Building
Bellevue, Washington 98009

Mr. Clinton P. Ashworth
Supervisor, Mechanical Engineering
Pacific Gas and Electric Co.
77 Beale Street
San Francisco, CA 94106

Mr. Robert L. Bolger
Commonwealth Edison Company
One First National Plaza
P.O. Box 767
Chicago, Illinois 60609

Mr. A. C. Dolbec
Electric Power Research Institute
3412 Hillview Ave.
P.O. Box 10412
Palo Alto, CA 94303

Heinz G. Pfeiffer
Manager
Technology & Energy Assessment
Pennsylvania Power & Light
Two North Ninth Street
Allentown, PA 18101

Mr. Homer T. McCarthy
Director, Generation Planning
Allegheny Power System
Cabin Hill
Greensburg, PA 15601

Mr. Kenneth E. Hogeland
Project Manager
Stone & Webster Engineering Corp.
P.O. Box 2325
Boston, MA 02107

Mr. Paul Probert
A.E. & E.S. Division
Babcock & Wilcox
P.O. Box 351
20 South Van Buren
Barberton, Ohio 44203

Mr. John H. Noble, P.E.
Charles T. Main, Inc.
Prudential Center
Boston, MA 02199

AGENDA

June 1, 1983

REVIEW MEETING

ENGINEERING ASSESSMENT
MHD RETROFIT

MOUNTAIN STATES ENERGY, INC.
BUTTE, MONTANA

TIME	DISCUSSION TOPIC
8:30	Welcome to Mountain States Energy
8:45	Project Overview
9:00	MHD Configuration & Components
10:30	Design Requirements
12:00	Lunch
1:30	Cost and Schedule
3:00	Tours of the Component Development and Integration Facility
5:00	Adjournment

ATTACHMENT #6

Milestone #5 Invoice

Mountain States Energy Inc.
POST OFFICE BOX 3662
BUTTE, MONTANA 59702

INVOICE

Date: May 9, 1983
Contract: DNRC Milestone V
Invoice No: DNRC-05

Department of Natural Resources
32 South Ewing Street
Helena, Montana 59620

Direct Labor	$ 9,423.02	
Fringe	3,743.29	$13,166.31
Overhead		5,291.93
Other Direct		
Travel	239.00	
Computer Support	460.16	
Contract Services	14,115.00	
Supplies		
Reproduction	16.97	14,831.13
General & Administrative		8,839.84
TOTAL COSTS		$42,129.21
Fee		5,062.50
TOTAL INVOICE		$47,191.71

ATTACHMENT #7

Estimate for Milestone #6

ESTIMATED COSTS

MILESTONE NO. 6

Direct Labor	$20,892.82	
Fringe	8,689.30	$29,582.12
Labor Overhead		11,241.55
Other Direct Costs		
Consultants	$12,950.00	
Travel	0	
Computer Support	0	
Reproduction	0	
Materials and Supplies	0	12,950.00
Direct Costs		$53,773.67
General and Administrative		11,742.53
Cost		$65,516.20
Fee		5,062.50
Price		$70,578.70

ATTACHMENT #8

Project Status & Schedule Project

MILESTONE SCHEDULE AND STATUS REPORT

1. Contract Identification Department of Natural Resources and Conservation

2. Reporting Period through

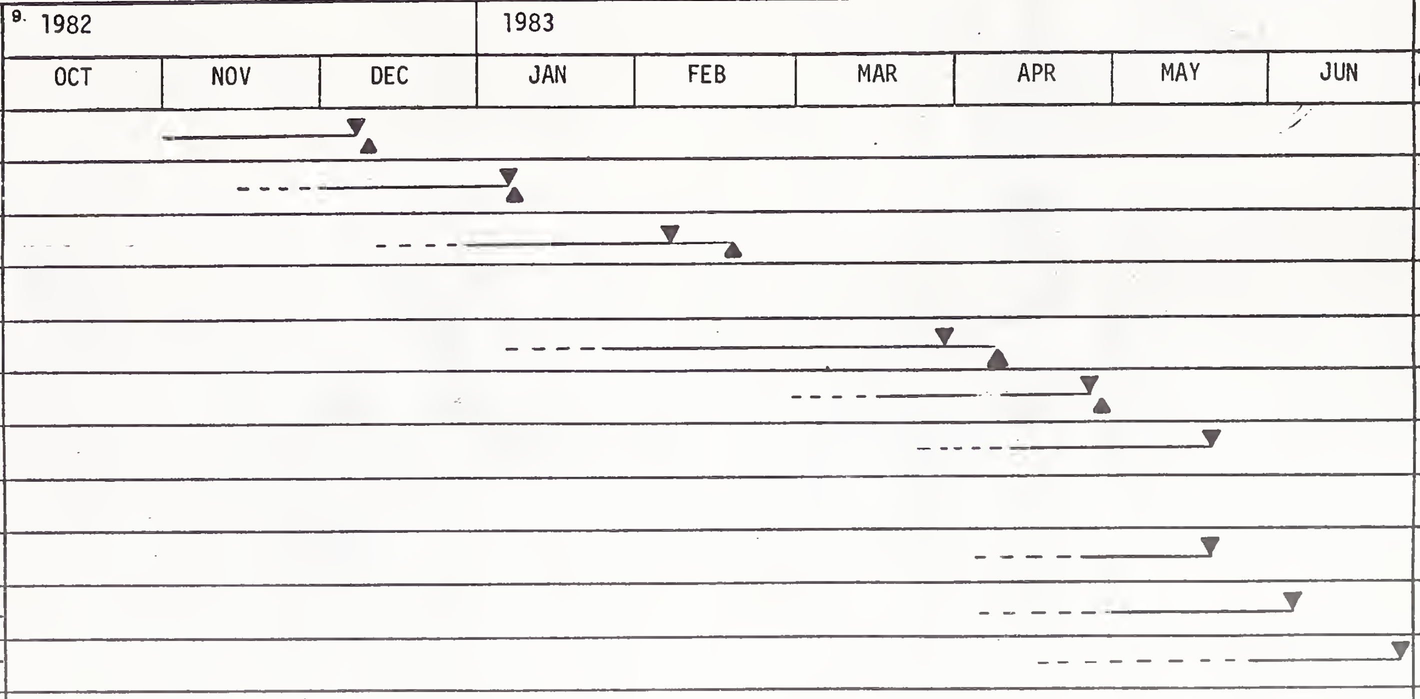
3. Contract Number

4. Contractor (name, address)
Mountain States Energy, Inc.
P. O. Box 3767
Butte, MT 59702

5. Contract Start Date November 1, 1982

6. Contract Completion Date June 29, 1983

7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	10. Percent Complete a) Planned	10. Percent Complete b) Actual
DNRA	DETERMINATION OF PLANT TO BE USED FOR RETROFIT		
DNRB	SPECIFICATION OF BASELINE CONFIGURATION		
DNRC	CONFIGURATION ANALYSIS		
DNRD	DETERMINE DESIGN REQMTS		
DNRE	REVISION OF DESIGN REQUIREMENTS		
DNRF	COST AND SCHEDULE ESTIMATES		
DNRG	IMPACT ON NATIONAL MHD DEVELOPMENT PROGRAM		
DNRH	DRAFT ENGINEERING ASSESSMENT		
DNRI	ISSUE ENGINEERING ASSESSMENT		

9.


11. Remarks

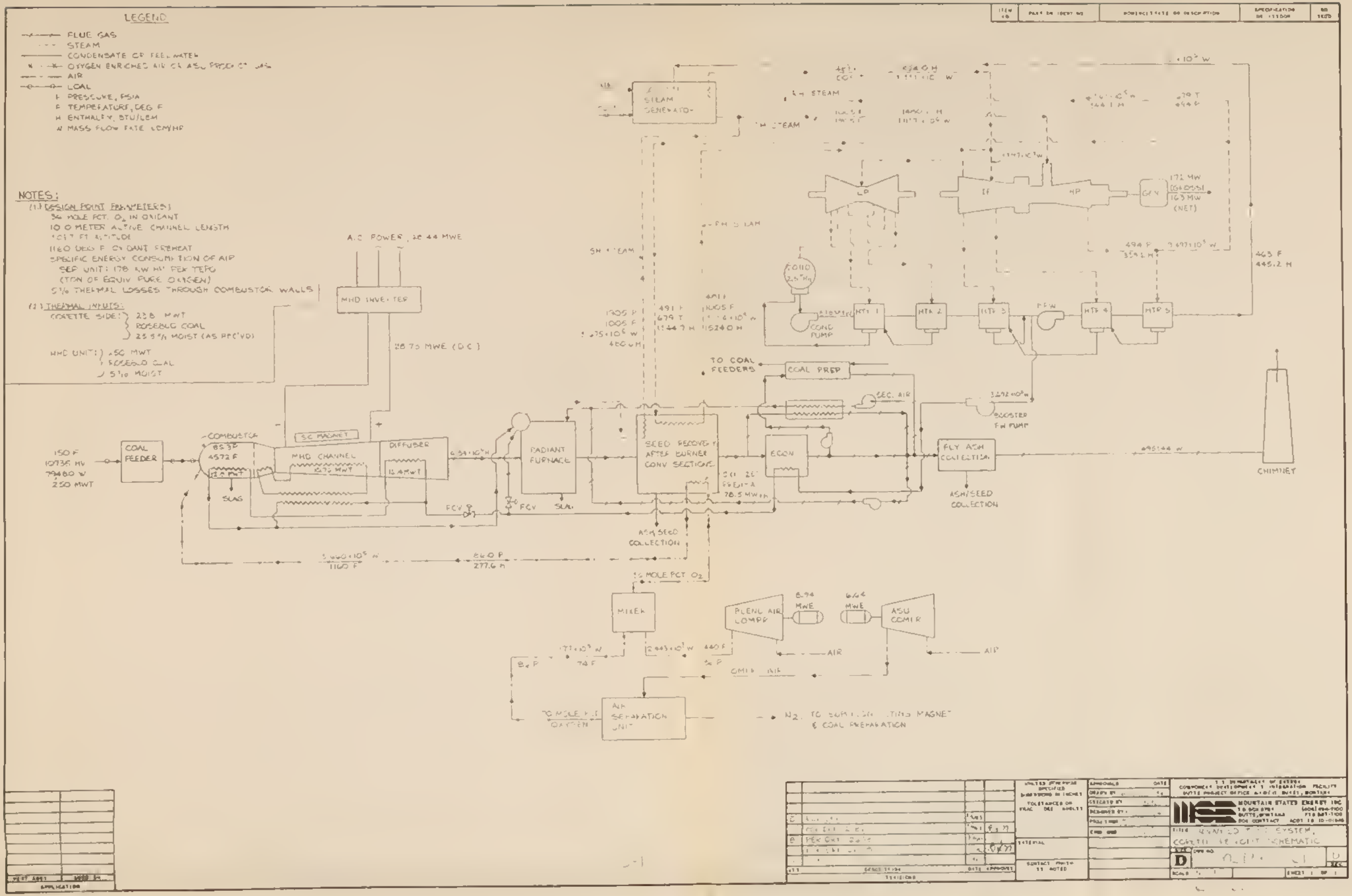
12. Signature of Contractor's Project Manager and Date

KEY MILESTONE LIST

	IDENT NUMBER	DESCRIPTION	SCHEDULED START	ACTUAL START	SCHEDULED COMPLETION	ACTUAL COMPLETION
1.	DNRA	DETERMINATION OF PLANT TO BE USED FOR RETROFIT SC - INITIATION OF CONTRACT WORK AS AUTHORIZED BY THE DEPT. CC - OBTAIN EEI CONCURRENCE AND SELECTION OF CANDIDATE MONTANA PLANT	11-01-82	11-01-82	12-07-82	12-10-82
2.	DNRB	SPECIFICATION OF BASELINE CONFIGURATION SC - SUCCESSFUL COMPLETION OF MILESTONE 1 AS INDICATED BY DEPARTMENT APPROVAL CC - THE ISSUANCE OF PRELIMINARY BASELINE SPECIFICATION TO BE USED FOR FOLLOW ON WORK	12-01-82	12-13-82	01-06-83	01-07-83
3.	DNRC	CONFIGURATION ANALYSIS SC - SUCCESSFUL COMPLETION OF MILESTONE 2 CC - THE ISSUANCE OF A PLANT CONFIGURATION TO BE USED FOR FOLLOW ON WORK	12-29-82	01-03-83	02-09-83	02-18-83
4.	DNRD	DETERMINE DESIGN REQUIREMENTS SC - SUCCESSFUL COMPLETION OF MILESTONE 3 CC - ISSUANCE OF A DRAFT DESIGN REQUIREMENTS TO TEN UTILITIES FOR CONCURRENCE	01-27-83	01-31-83	03-30-83	04-08-83
5.	DNRE	FINALIZATION OF DESIGN REQUIREMENTS SC - SUCCESSFUL COMPLETION OF MILESTONE 4 CC - OBTAIN UTILITY CONCURRENCE	03-14-83	03-21-83	04-26-83	04-29-83
6.	DNRF	COST AND SCHEDULE ESTIMATES SC - SUCCESSFUL COMPLETION OF MILESTONE 5 CC - ESTIMATED COST OF MHD RETROFIT AND SCHEDULE FOR RETROFIT ACCOMMODATION	04-11-83	04-20-83	05-17-83	
7.	DNRG	IMPACT ON NATIONAL MHD DEVELOPMENT PROGRAM SC - COMPLETE MILESTONE 5 OR APPROVED BY THE DEPARTMENT CC - RECOMMENDATION TO THE NATIONAL MHD PROGRAM	04-18-83	04-20-83	05-17-83	

KEY MILESTONE LIST

	IDENT NUMBER	DESCRIPTION	SCHEDULED START	ACTUAL START	SCHEDULED COMPLETION	ACTUAL COMPLETION
8.	DNRH	DRAFT ENGINEERING ASSESSMENT SC - COMPLETE MILESTONES 6 & 7 CC - ISSUE DRAFT ENGINEERING ASSESSMENT	05-02-83		06-07-83	
9.	DNRI	FINALIZE ENGINEERING ASSESSMENT SC - COMPLETE MILESTONE 8 CC - ISSUE FINAL ENGINEERING ASSESSMENT	05-25-83		06-29-83	



NOTES:

(1) DESIGN POINT PARAMETERS:
36 MOLE PCT. O_2 IN OXIDANT
10.0 METER ACTIVE CHANNEL LENGTH
[illegible] FT ALTITUDE
1160 DEG F OXIDANT PREHEAT
SPECIFIC ENERGY CONSUMPTION OF AIR
SEP UNIT: 178 KW HR PER TEPO
(TON OF EQUIV PURE OXYGEN)
5% THERMAL LOSSES THROUGH COMBUSTOR WALLS

(2) THERMAL INPUTS:
CORETTE SIDE: 238 MWT
ROSEBUD COAL
25.5% MOIST (AS REC'VD)

MHD UNIT: 250 MWT
ROSEBUD COAL
5% MOIST

U.S. DEPARTMENT OF ENERGY
COMPONENT DEVELOPMENT & INTEGRATION FACILITY
BUTTE PROJECT OFFICE [illegible] BUTTE, MONTANA

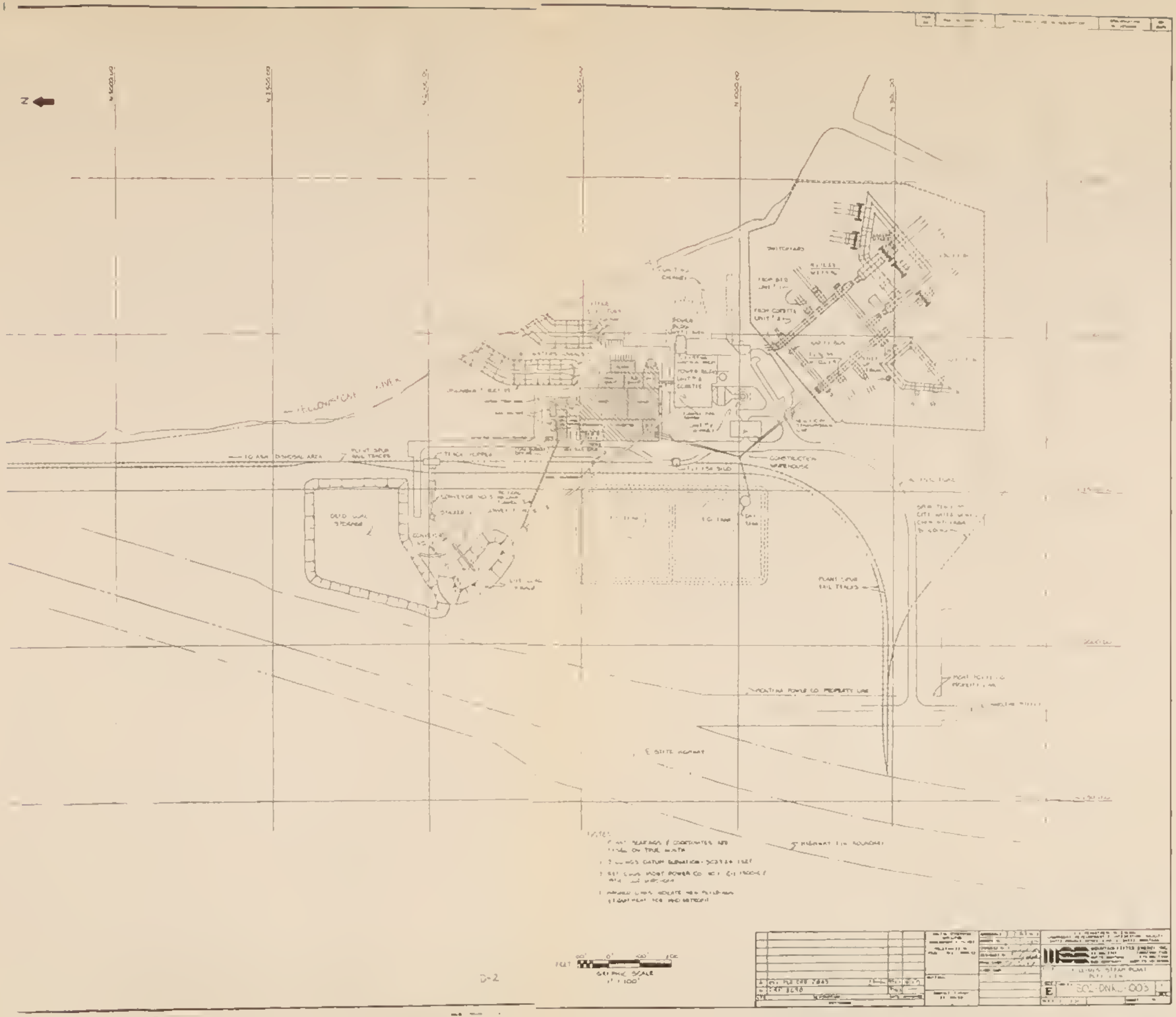
MOUNTAIN STATES ENERGY INC
BUTTE, MONTANA

TITLE [illegible] SYSTEM,
CONCEPTUAL [illegible] SCHEMATIC

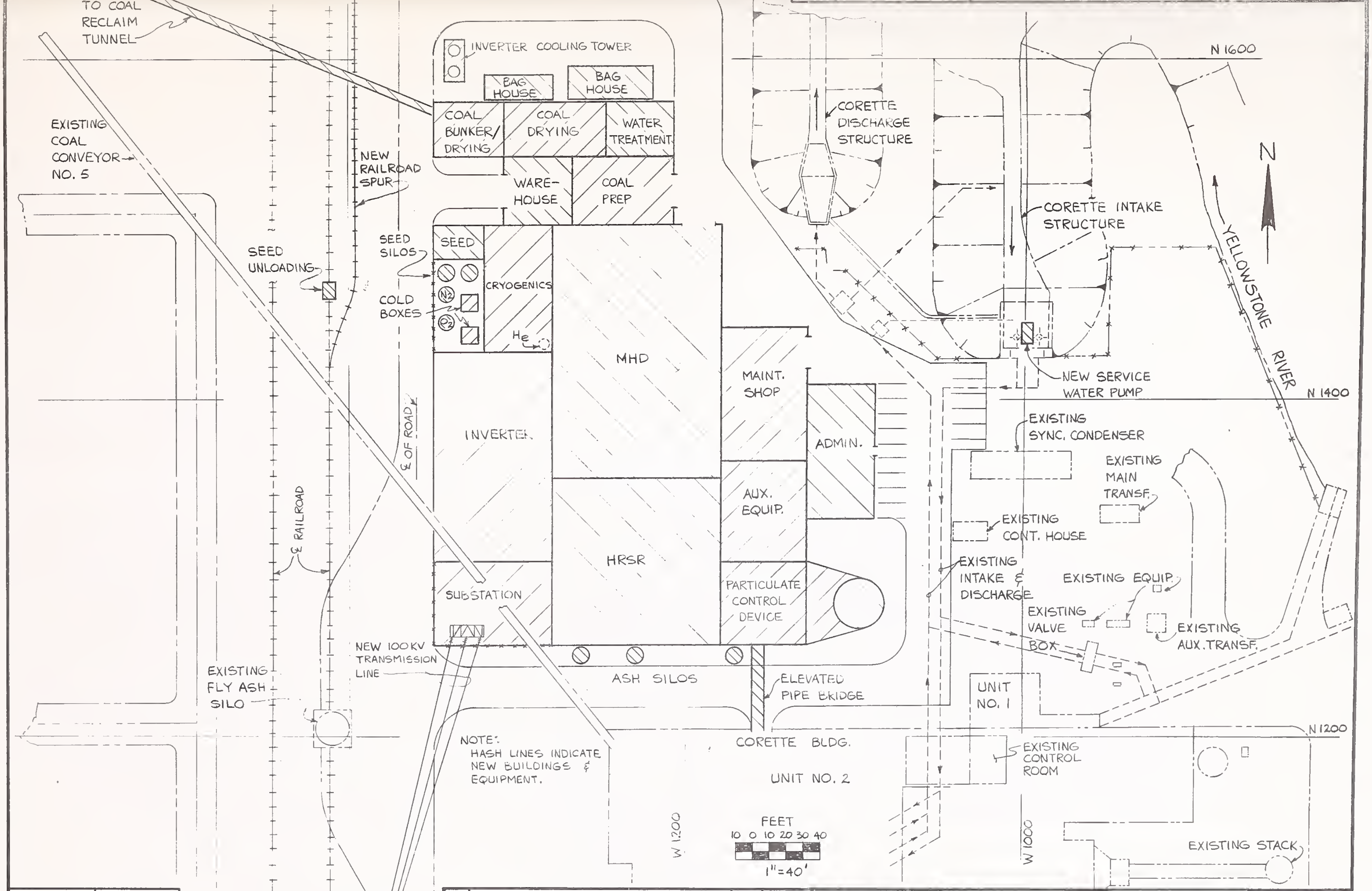
SIZE D

SCALE

SHEET 1 OF 1


N
YELLOWSTONE RIVER
SWITCHYARD
POWER BLDG UNIT 3 & 4
POWER BLDG UNIT 1 & 2
TO ASH DISPOSAL AREA
PLANT SPUR RAIL TRACKS
TRUCK HOPPER
CONVEYOR NO. 3
DEAD COAL STORAGE
CONSTRUCTION WAREHOUSE
PLANT SPUR RAIL TRACKS
MONTANA POWER CO. PROPERTY LINE
MONT POWER CO PROPERTY LINE
℄ STATE HIGHWAY
HIGHWAY R/W BOUNDARY
NOTES:
GRAPHIC SCALE
1" = 100'
FEET
E
E02-DNA-003

ITEM NO.	PART OR IDENT. NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION OR VENDER	NO. REQ'D



NEXT ASSY.	USED ON
APPLICATION	

LTR.	DESCRIPTION		DATE	APPROVED
A	DRR 2843	[illegible]	5/3/83	[illegible]
+	DRR 2698		4/5/83	—

REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES ON
FRAC. DEC. ANGLES

MATERIAL:

SURFACE FINISH AS NOTED

APPROVALS	5-24-83 DATE
DRAWN BY: [illegible]	
CHECKED BY: R J Buckmaster	
DESIGNED BY: R J Buckmaster	
PROJ. ENGR. [illegible]	
ENGR. MGR.	

U.S. DEPARTMENT OF ENERGY
COMPONENT DEVELOPMENT & INTEGRATION FACILITY
BUTTE PROJECT OFFICE MHD/ID BUTTE, MONTANA

MOUNTAIN STATES ENERGY INC.
P.O. BOX 3767 (406) 494-7100
BUTTE, MONTANA FTS 587-7100
DOE CONTRACT AC07-78-ID-01948

TITLE: CORETTE PLANT MHD RETROFIT

SIZE C | DWG. NO. C02-DNRC-004 | REV. A

SCALE: 1"=40' | SHEET 1 OF 1